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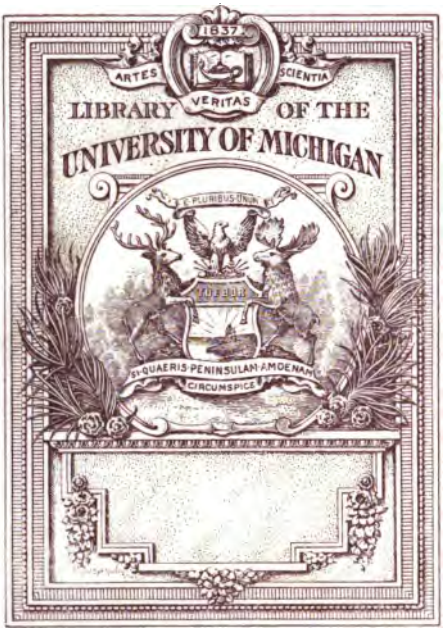
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THE PRINCIPLES AND PRACTICE OF COAL MINING

THE
PRINCIPLES AND PRACTICE
OF
COAL MINING

BY

JAMES TONGE, M.I.M.E., F.G.S.

WITH 203 ILLUSTRATIONS

London
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PREFACE.

In preparing this volume the author has had in mind the needs of two classes of students. First, those who intend to adopt mining engineering as a profession; and, secondly, practical miners seeking to secure certificates as Colliery Managers or Under Managers, or preparing for the examination of the Board of Education.

The science of mining so largely consists of practical applications of geology, mechanics, physics, chemistry, and other branches of natural knowledge, that it has proved difficult in many cases to decide what acquaintance with these subjects on the part of the reader to take for granted. The author is hopeful that sufficient information has been given to make the book self-explanatory, but students are urged to study these collateral sciences as fully as circumstances permit.

Release 1-10-40 mgp

Acknowledgments are gratefully made to many friends who have willingly supplied information in regard to the latest forms of mining machinery and equipment; to Prof. Edward Hull, F.R.S, and to M. André for permission to make use of their standard works on the "Coal Resources of Britain" and "Coal Mining" respectively; to Mr. W. E. Garforth and the Institution of Mining Engineers for permission to include the suggestions on the recovery of life after explosions; to the proprietors of *Mines and Minerals* for permission to reproduce many articles contributed to that journal by the author; to

159306

the editor of the same periodical for valuable assistance; and to Mr. A. J. Tonge for numerous important suggestions and help in the revision of proofs.

Finally, the author desires to record his indebtedness to Prof. R. A. Gregory and to Mr. A. T. Simmons; only those who have been under a similar obligation can appreciate the trouble and pains taken by them; in fact, without their help this book at any rate would not have been written.

J. TONGE.

WESTHOUGHTON,
December, 1906.

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THE PRINCIPLES AND PRACTICE OF COAL MINING

CHAPTER I.

PROSPECTING.

Geology in Relation to Coal Mining.—The term coal mining includes those processes by which seams of coal are explored and extracted and the product dressed. It includes the search for seams of coal, the operations by which these seams are won, and the arrangements adopted for their utmost utilisation.

Of these three operations, the first is by no means the least important, and it follows, therefore, that a close acquaintance

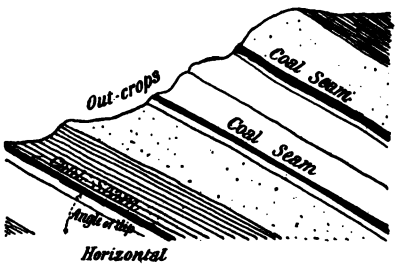


FIG. 1.—Outcrops of Coal Seams and Intermediate Strata.

with the form, position, and character of the rocks which constitute the crust of the earth is necessary to the miner.

Large tracts of the earth's surface have been carefully examined, and their features noted and minutely described. The position and direction of *faults* (Figs. 2, 3 and 4), which are

throws or dislocations of the earth's crust disturbing the continuity of the beds of rock, have been recorded and mapped wherever possible. Other information in regard to every known seam of coal has been similarly treated where practicable. *Outcrops* (Fig. 1), which are those portions of strata appearing at the surface, or occurring immediately below the surface soil, have been shown on geological maps, and the *rate of dip* (Fig. 1), that is, the amount of inclination of the seam with a horizontal plane, denoted.

The strata passed through in sinking, tunnelling and mining have been noted, especially during recent years, and fossils have been collected; and the results have been embodied in geological maps and sections. This great mass of information, representing the results of exploration and scientific research, has been carefully classified, the facts learnt from them have been compared and used, and highly important laws and theories have been based upon the material. Perhaps the most important of these laws for the coal miner is the one which leads to the conclusion that the different beds of rock are found in a definite descending order, and amongst these the *true Coal Measures occupy one well-defined vertical position everywhere.* Certain rocks may be missing—left out altogether—and perhaps at no place is a complete section of the earth's crust found, but that does not alter the fact that order reigns, and that an early formation is rarely found on the top of a newer, and *vice versa.* Consequently, it is a mistake to suppose that the mining student should confine his studies to the particular formation —the Carboniferous—in which the main coal seams are found. Each group of the whole series of rock formations has some secret to impart to the careful student, which may enable him to arrive at important results.

A knowledge of the various rocks was necessary even when only those coal fields were developed where the Carboniferous rocks are at the surface, but now that new areas must be proved, lying in many cases beneath considerable thicknesses of newer and little-known formations, the necessity for geological knowledge is imperative.

Prospecting.—Two great classes of minerals are worked, viz.: *Metallic* and *Non-Metallic.*

A **mineral** is any constituent of the earth's crust having a definite chemical composition which does not vary from part

to part of its mass. **Metallic minerals** are those like Gold, Silver, Copper, and Iron, having certain distinctive characters, *e.g.* bright lustre and heaviness, and are good conductors of heat and electricity. The **Non-Metallic minerals** include Coal, Salt, Limestone, Slate, and Gypsum; these differ from the metallic minerals in lustre, weight, and conductivity.

It is clear that the method of searching for the different metallic and non-metallic minerals cannot always be the same. Irregular veins, or deposits of gold and other metals, must be looked for in a different manner from the comparatively regular seams of coal or ironstone. The former generally occur in rocks that have undergone considerable metamorphism or change, while non-metallic minerals are generally found in beds or stratified deposits. In searching for metals, therefore, regions must be chosen where great disturbances and upheavals have occurred, accompanied by great contortions of the rocks, eruptions of volcanic matter, and the formation of faults and veins. The search for these is often difficult. On the other hand, the search for coal is rendered comparatively easy, owing, as we have already said, to the great amount of information already available in regard to most coal-bearing formations.

If on entirely new ground, it is necessary for the prospector first to consult geological maps, sections and memoirs, published by the Geological and Ordnance Surveys. These publications give full details of the surface of the locality, *e.g.* the course of rivers, streams, railways, canals and roadways, and the position of buildings, etc.; of contour lines, that is, lines joining all points on the surface having the same height above sea-level, and, so far as can be ascertained, the inclination and outcrops of the strata and the dimensions and directions of faults. Information in regard to adjoining properties may be obtained possibly from colliery proprietors or managers, and having thus to some extent acquired a knowledge of the district generally, it becomes necessary to make a thorough examination of the surface, and to study the exposed rocks in the area where the presence of coal is suspected. The characteristics of each different bed, as revealed in cuttings, valleys, wells or old shafts; their composition, texture, thickness, and rate of dip must be carefully noted, and samples and fossils collected. Signs of vertical displacements, faults or other breaks in the strata must be looked for, and all possible information regarding them ascertained.

Very often coal outcrops contain springs which carry a certain quantity of iron in solution, and a reddish ochry deposit may often be discovered on the stones and vegetation over which the streamlets flow. Alterations in the contour of the land, causing terraces or sudden changes in the vegetation, may often serve as a guide to outcrops of coal. In the explorations, careful measurements must be taken horizontally and vertically of the different changes in the strata, and these measurements may be entered in some such form as that shown in the accompanying table:

No.	Name.	Colour.	Texture.	Thickness.	Direction of Dip.	Rate of Dip.	Point of Outcrop.	Fossils or other Peculiarities.
				ft. in.			yards	
1	Sandstone,	White,	Fine,	3 0	S. 30° W.	10°	0	—
2	Sandstone,	Red,	Coarse,	3 0	,,	,,	0	—
3	Shale,	Bluish,	Fine,	2 6	,,	,,	0	—
4	Ironstone,	Reddish,	Very close,	2 3	,,	,,	20	—
5	Burrstone,	Brown,	Fine,	2 0	,,	,,	35	—
6	Warrant,	Dark,	Spikey,	2 0	,,	,,	45	—
7	Coal,	—	Thin,	1 0	,,	,,	55	Good Coal.
8	Shale,	Grey,	Slatey,	2 6	—	—	75	Ferns Neuropteris.
9	Sandstone Rock,	Light red,	Fine,	2 6	—	—	93	—
10	Metal,	Grey,	Coarse,	3 0	—	—	115	—

Having thus carefully noted all surface indications of the presence of coal, it will be necessary further to prove its actual occurrence by boring vertical holes, or by driving tunnels or levels through the strata. If the measures are fairly flat, the greatest information will be obtained by vertical bore holes. But with highly inclined strata, or in hilly regions, horizontal tunnels driven so as to intercept the succeeding beds, will disclose more readily the existence or non-existence of seams.

In the search for and ultimate identification of coal seams, three disturbing elements will probably be experienced: variations in the rate of dip of the measures; the occurrence of faults or dislocations; and changes in the thicknesses of the various beds. These elements certainly render the work of exploration difficult even in familiar ground, and necessarily great care must be taken in observing and recording all changes in the strata. If the assistance of men who have had experi-

ence in boring, sinking and tunnelling can be obtained, the difficulties in this respect may be reduced.

Formations containing Coal.—Seams of coal occur in the strata of most geological ages from the oldest to the newest; and the following table,[1] giving the names of all the geological formations in regular descending order, shows also the formations in which coal is now worked in various parts of the world:

Period.	Formation.	Countries where Coal Seams are Worked.
Tertiary or Cainozoic	Recent.	
	Pleistocene.	
	Pliocene, - -	Italy.
	Oligocene, - -	N. Germany.
	Eocene, - -	Washington, U.S.A.
Secondary or Mesozoic	Cretaceous, - -	British Columbia, Hanover.
	Wealden-Purbeck.	
	Oolitic, - -	Sutherlandshire, Hungary, Tonkin.
	Liassic.	
	New Red Sandstone — Triassic, -	Virginia and N. Carolina, U.S.A., India, Queensland.
	New Red Sandstone — Permian, -	Cape Colony, Natal, Transvaal, New S. Wales.
Primary or Palaeozoic	Carboniferous, -	British Isles, France, Belgium, Germany, Austria, Spain, Pennsylvania.
	Old R. Sandstone.	
	Devonian.	
	Silurian.	
	Cambrian.	

As a rule, the coal found in recent formations is *lignite* or *brown coal*, an inferior quality of fuel which has not undergone the same degree of chemical change as good coal, owing to the fact that less time since its original deposition has been available for its formation. The deposits worked in the Primary and Secondary rocks are true coal. The bulk of the best coal, not only in this country, but in Belgium, France, Germany and the United States, is found in the Carboniferous rocks, where the true Coal Measures contain the most numerous, extensive, and valuable seams.

[1] Based upon a similar table in the late Sir Le Neve Foster's *Elements of Mining* (Griffin).

The Carboniferous Period.—This system of rocks may be divided as follows:

Upper or true Coal Measures, { Upper / Middle / Lower } Coal Measures.

Millstone Grit.

Carboniferous or Mountain Limestone and Calciferous Sandstone.

In the British Isles these rocks are found in the Northern and Midland Counties of England, in North and South Wales, and in Gloucestershire, Somersetshire, Ireland and Scotland. They attain a total thickness of about 18,000 feet.

The Coal Measures contain the main seams of coal. They extend a vertical distance of between seven thousand and eight thousand feet, are composed of sandstones, shales, limestone bands, and beds of coal, fireclay and ironstone. In most coalfields in this country the most productive are the middle coal measures, few seams being found in the upper, and only two or three workable beds in the lower. In South Wales, however, the best seams are found in the Lower series, while in Scotland valuable seams of coal are found even below the Millstone Grit, in the Carboniferous Limestone and in a series of rocks lying immediately below—the Calciferous Sandstones.

The Seams of Coal vary in thickness from a few inches to 30 feet; in some countries seams of more than a hundred feet in thickness are to be found, and many good seams have been, or are now being, worked, though generally thick deposits are not of uniformly good quality. The best seams are generally less than seven or eight feet thick, and the quality of some thin seams of 18 or 20 inches is often so good that they can be profitably worked.

Stratified Ironstone, Oil Shale, and Fireclay.—These minerals occur very often in conjunction with coal seams; and in certain coalfields, such as those of Cumberland, Durham, Lancashire, Yorkshire, North and South Wales, North and South Staffs, Derby, Notts, Warwickshire and Lanarkshire, valuable deposits are worked, the proximity of the coal making its winning a simple and inexpensive matter. There are various kinds of iron ores, some of which are not found adjacent to coal seams, and occur as irregular veins or deposits, such as magnetite, specular iron ore, etc. The chief iron ores found

in the coal measures are: *Brown hematite, spathic, clay ironstone, black-band ironstone* and *iron pyrites.* These minerals are found often either in the seams themselves, in the clay immediately below, or in the strata immediately above or below the seams. Stratified ironstone is also met with in the Secondary or Mesozoic formations.

Stratified Ironstone of the Coal Measures.—Brown Hematite.—Brown iron ore, or hematite, is rich in iron, but does not occur in this country in connection with coal seams except in the Forest of Dean, where it contains 89 per cent. of ferric oxide, Fe_2O_3, in which iron and oxygen have combined in the proportions shown by the formula. Ferric oxide occurs in many places in this simple form as red hematite. Combined with water it forms brown hematite and yields exceedingly pure iron. It is found in large quantities in Lorraine, Luxemberg, and Northern Spain.

Spathic contains chiefly ferrous oxide, FeO, and produces about 50 per cent. of iron. It is mixed with carbonate of lime as a rule, and is found in fairly large quantities in Somerset, Durham, Westphalia and Prussia.

Clay Ironstone is found in the beds of clay in conjunction with coal, fireclay, millstone grit, and limestone. These and the black-band ironstones are the chief varieties worked in connection with collieries. In Derbyshire, Yorkshire and Northumberland, the millstone grits contain thin seams of coal and ironstone. In South Staffordshire, Nottinghamshire, Warwickshire, North and South Wales, it is met with in large quantities. Although mixed with other minerals to a rather large extent, the latter are easily got rid of by calcining—that is, driving them off by combustion in the form of gases, leaving only the oxide of iron, which contains about 35 to 40 per cent. of iron.

Black-band Ironstone is very similar to clay ironstone, but as it occurs as a rule in immediate proximity to the coal it contains more or less bituminous or coaly matter. It is found overlying some coal seams, and because of its formation in dark layers and its banded appearance, it is called black-band ironstone. In North Staffordshire it occurs in the upper portion of the Coal Measures, and in this coal field and in Lanarkshire is worked in large quantities. On account of the large quantities of combustible matter present, the mixture of fuel with the

ore before calcining is unnecessary. It contains as a rule 30 per cent. of pure iron, with quantities of coaly matter varying from 15 to 30 per cent.

Stratified Ironstone of the Secondary Rocks.—In some parts of the Midlands, Yorkshire and the Isle of Man rocks of organic origin are met with containing iron, generally in the form of carbonate of iron. In these cases the rocks are usually limestone, in which the carbonate of iron has partially or entirely taken the place of the carbonate of lime. A bed of this kind of ironstone is worked in the Cleveland district of Yorkshire; it occurs in the Liassic formation and is about 10 feet thick.

Oil Shale.—In the lower Carboniferous rocks, bituminous shales are sometimes found containing a certain amount of oil, which can be obtained by distilling. Cannel coals often pass gradually into bituminous shales, and these shales are often so loaded with coaly matter that large quantities of oil can be distilled from them. It is chiefly in the bituminous shales of Scotland that this occurs, and oil-shale must not be confused with the mineral oils extracted by wells from certain parts of America and Southern Russia.

In Derbyshire, Lancashire, Yorkshire and Northumberland, the Carboniferous or Mountain Limestone contains thin bands of shale, which gradually go thicker towards the north until thin seams of coal appear, indicating the existence at one time of a shore line in this direction. In Scotland, however, the base of this limestone has a series of rocks 6,000 feet thick, called the Calciferous Sandstone series, in the upper part of which occur rocks known as the oil shale group. This group of rocks has thin beds of coal near the top, with several seams of oil shale interstratified with beds of sandstone, argillaceous shale, and fireclay. The oil shales, of course, differ greatly in the amount and quality of oil produced. In some cases as much as 30 gallons can be extracted per ton of shale. Some shales produce oil more rich in bye-products, such as sulphate of ammonium, it being found that the deeper seams are as a rule richer in this than the shallower ones.

Fireclays are the clays which are found under many seams of coal. They consist chiefly of silica and alumina, and are generally found to be free from lime and alkalies, these minerals having been absorbed by the roots of growing plants. When made into bricks, crucibles and retort pipes, fireclay will

resist very high temperature, and it is of such great value in this respect that mines of fireclay are worked even where the coal above is of no commercial value.

Characteristics of Coal Seams which aid in their Identification.—It is quite necessary that the miner should be able to identify seams of coal when they have been found, and to correlate them if possible with the seams in adjacent mines or neighbouring coalfields. It is sometimes thought that an accurate idea of what the seam is can be formed generally from the character of the strata being passed through in sinking, before the coal is actually reached. But this is not always possible, as not only do the thicknesses of the various strata vary considerably in different places, but seams are sometimes missing altogether, and calculations based on their relative positions are thus considerably upset. The safest plan is to examine carefully every seam of coal passed through; to keep a careful record of their every feature; to note their relationship to the immediate overlying or underlying strata; and their distances from each other.

The main features to be observed, which will assist in the identification of the seams, are as follows:

1. The general appearance and structure of the coal.
2. The number, thickness and quality of the various beds or layers of which the seam is made up.
3. The number, thickness and quality of the interlying bands of ironstone, fireclay, or impurities.
4. The number and direction of breaks, etc., in the coal.
5. The fossils in the coal or accompanying strata.
6. The constitution of the roof and floor.

With carefully obtained evidence of this kind, seams of coal must form the best horizons, as they present more distinctive features than can be found in the interlying strata, and these features are general over wider areas than is the case with those of the latter.

Faults.—Faults are fractures or dislocations of the strata which interfere with the continuity of the beds. Originally, as has been shown, the beds were laid down horizontally, but owing to violent disturbances in the earth's crust they have been distorted or displaced in various ways. These disturbances may have been caused either during or subsequent to the deposition of the strata. In some cases a portion of a bed or

seam may have been denuded by a stream of water; this is called a **wash-out.** Most faults are caused by disturbances taking place after the formation of the strata, and these are more correctly termed **faults, throws, heaves** or **slides.**

The **throw** of a fault is the amount of vertical displacement; it is measured vertically from the top or bottom of a seam on one side of the fault (*AB*, Fig. 2) to the top or bottom on the other side; it must not be measured from the top of a seam on one hand, to the bottom of the seam on the other.

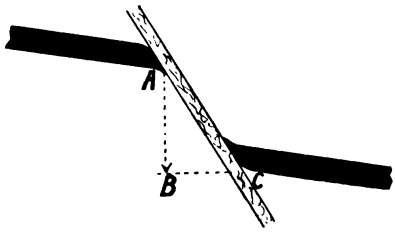


FIG. 2.—An Ordinary Fault.

The **hade** of a fault is the inclination of the fault from the perpendicular, and may be measured in degrees, or in the number of feet from the vertical represented by the line *BC* (Fig. 2).

The **dip** of a fault is the inclination of a fault from the horizontal plane, or the angle made with the horizontal plane, and is measured in degrees.

The **matrix** or irregular rocks forming the line of breakage is generally termed the **listing.**

A **downthrow fault** is one in which the coal may be looked for at a point lower than that at which the fault is first met with. If the fault was first encountered when working at or near the roof of the seam, this would be a downthrow except in the case of a reversed fault.

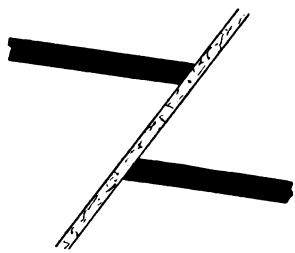


FIG. 3.—A Reversed or Overlap Fault.

An **upthrow fault** is one in which the coal may be looked for on the higher side of the point where the fault is first met with. If the fault was encountered when working at or near the floor of the seam, this would be an upthrow fault except in the case of a reversed fault.

An **ordinary fault**, also called a **normal fault**, is one in which the dislocation has been a simple slip or break, as in Fig. 2.

A **reversed or overlap fault** (Fig. 3) is one in which the beds are so displaced as to cause the lower side beds to be found under the higher side beds, which is quite opposite to the method of occurrence of the beds in ordinary faults.

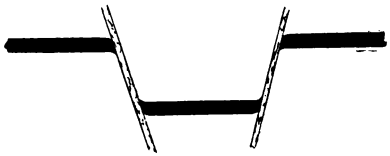


FIG. 4.—A Trough Fault.

A **trough fault** is one in which the strata is thrown down between two faults, as in Fig. 3.

Questions on Chapter I.

1. In what way does geological evidence assist the searcher for coal and other minerals?

2. How would you proceed to search or "prospect" for minerals in a new country? What indications would you specially look for? (1901.)

3. Describe the terms *outcrop* and *rate of dip*.

4. How are the Carboniferous strata classified in Great Britain? (1898.)

5. What are the Coal Measures and how are coal and other minerals distributed in them? (1894.)

6. In what other formations besides the Carboniferous do workable seams of coal occur, and in what countries are these seams worked?

7. Describe the principal deposits of iron ore which are being worked in the British Isles. (1901.)

8. What is Oil Shale? Name the geological horizons at which it is known to occur in the British Isles. What useful substances are obtained from it? (1901.)

9. What is fireclay? How does it generally occur in conjunction with coal seams?

10. If in searching for coal you struck a good seam, how would you proceed to identify it?

CHAPTER II.

COALFIELDS.

Formation of Coalfields.—It is a well-known feature of the British coalfields, and of the European coalfields generally, that they rest **conformably** on the Old Red Sandstone, or Devonian formation, that is to say the stratification of the newer Carboniferous rocks is in the same direction, or the beds make the

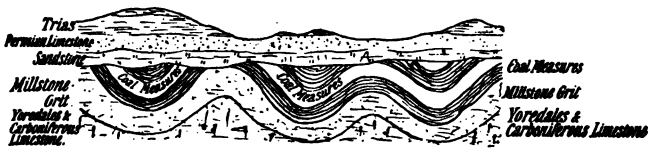


FIG. 5.—Section of Strata showing Coal Measures lying conformably on Millstone Grit and overlain unconformably by Permians.

same angle with the horizontal, as those of the older Devonian rocks. Moreover, there has been no great break in the process of deposition of the Carboniferous rocks upon the older Devonian formations—the process has gone on regularly without any great period of geological time between the time of deposition of the two formations. On the other hand, the Carboniferous is generally overlain **unconformably** by the Permians or New Red Sandstones (Fig. 5); in other words, the latter rocks rest on the Carboniferous at a different angle of stratification; and between the time when the Carboniferous rocks were thrown down and the period of deposition of the Permian strata, there was a break in the geological record during which time the Carboniferous rocks were subjected to great earth movements. Where this is the case, it is generally

found that the rocks of the older formation occur in a series of **synclines** and **anticlines** forming basins (Figs. 5 and 6), which have been caused by foldings, shrinkings or other disturbances of the earth's crust at a time antecedent to the deposition of the newer rocks.

FIG. 6.—Anticlines and Synclines.
(From a photograph by Mr. J. C. Christie, F.G.S.)

When the strata as seen in a section rise on each side from a central line, the curve or trough is said to be a syncline, and the hollow is termed a **synclinal curve** or **synclinal axis**. If the strata dip away from a central line or axis towards a hollow on each side the ridge or arch is said to be an anticline. After the disturbances forming these anticlines and synclines took place, denudation began and subsequently new deposits were thrown down at angles of stratification entirely different in most cases from that of the rocks on which they lie. This characteristic basin-like form of the Coal Measures frequently causes the seams to crop out at the surface, and thus greater areas of coal occur at a workable depth than would otherwise be the case. It is not often that the seams are found to crop out on all sides of the basin, but nevertheless the anticline may be

brought so near the surface, as in Fig. 5, as to be easily reached.

In England the Coal Measures rest on the Millstone Grit, this again on the Yoredale Series, and these pass gradually downwards into the Carboniferous Limestone. In Lancashire the Millstone Grit is 5,000 feet thick, in North Staffordshire 4,000 feet, in the Bristol coalfield 1,200 feet and in South Wales from 400 to 1,000 feet. These rocks consist of hard, coarse grits with bands of shale, and, in the Midlands and the north of Britain, of flagstones and sandstones and a few seams of coal.

FIG. 7.—Forest Bed at Leasowe, Cheshire, made up of peat, upright stumps of trees, and roots of the oak, fir, birch and other trees. The bed is under 6 feet of water at high tide.

(*From a photograph by Mr. C. A. Defieux.*)

In the Southern counties, where it contains no coal seams, it is known as the "Farewell Rock."

It is generally agreed by geologists that the great area extending from near the north of Scotland to the Southern counties of England on one hand, and from the West of Ireland across Scotland and England and into France, Belgium and Germany on the other, constituted an area on which the Carboniferous Limestone was laid down; and upon this, which at this time was probably a great shallow estuary, with bars of land stretching here and there, as across the Midlands, the sediments of the Millstone Grit accumulated, filling the sea up gradually, until at certain points forests began to grow. The accumulations gradually extended, and the forests gradually spread until during Coal Measure times the whole of Britain

was covered by them. These were afterwards covered up by new sediments, and these in their turn again supported vegetation.

This process continued for an enormous length of time until the whole of the seams of coal with their interlying strata were laid down. At the end of the Carboniferous period, great movements of the earth's crust took place. The rocks were probably first folded by an east and west force so that the axes of the folds and the strike of the rocks ran north and south, causing the outcrop along the Pennine Chain. Subsequently crushing from an opposite direction caused folds to run east and west, with the important result that the Carboniferous rocks chiefly occur in basins, the centre of which is filled by the Coal Measures.

The section of the rocks across the Pennine Chain and the Coalfields of Lancashire and Yorkshire shows that the Coal Measures, which were once continuous across both counties, after being folded were separated by denudation and thus separate coal basins exist on the east and west side of the chain. The outcrops are not always thus laid bare, newer formations sometimes completely cover them up, but a somewhat similar process has been at work in all the coalfields.

Geological Sections.—In order to represent the position, thickness and dip of the beds, sections are made which may be termed vertical or horizontal exposures of the strata, that is to say, they represent the rock strata as cut by a vertical or a horizontal plane. In the **Horizontal Section** of rocks just referred to, the position, relative thickness and rate of dip of the rocks forming the Pennine Chain and the Lancashire and Yorkshire coalfields are shown. If the section is taken in the direction of the dip, the true amount of inclination will be shown, and this will grow less and less as the direction is brought more in line with the strike; when taken along the strike the measures will appear horizontal. A **Vertical Section** is a section taken at a particular point and shows only the nature and thickness of the various beds.

Coalfields of Great Britain.—The question of the probable exhaustion of the coal seams of this country has long been of interest to those engaged in mining. By exhaustion, of course, is not meant the complete abstraction of every ton of coal in the earth's crust. This is impossible, as there will always remain many seams of coal which are too thin, or too poor

in quality, to be opened out; seams which have been abandoned owing to water or firedamp or bad roofs, and, finally, seams at such a depth from the surface that all known methods for the working, winning and ventilating of coal seams would be powerless to overcome the natural difficulties certain to be met with, so that unless new means are discovered vast stores of fuel will remain untouched.

The period of exhaustion may be said to have commenced, however, when the workable seams are either all worked out or are of such a quality as to be commercially valueless.

Amount of Coal Available.—Professor Hull (1860) calculated that the British coalfields contain approximately 80,000 millions of tons down to a depth of 4,000 feet, but this does not include seams of a thickness less than two feet, and does not take into consideration the existence of seams overspread by formations newer than the Carboniferous.

According to the estimates of the Royal Commission appointed in 1871 to inquire into the probable duration of the coal supply, the available resources of the country in seams of one foot thick and upwards, situated within 4,000 feet of the surface, were about 90,207,285,000 tons.

In the Final Report of the Royal Commission on Coal Supplies (1905) the amount still available of the same thickness and within the same distance of the surface is given as 100,914,668,167 tons. We see therefore that in spite of the great quantity of coal which has been worked since 1871, which statistics show has amounted to 5,694,928,507 tons, the present estimates of coal still available are nevertheless 10,707,382,769 tons in excess of those of the previous Commission. This excess is accounted for partly by the difference in the areas regarded as productive by the two Commissions, and partly by the more certain information revealed by recent borings, sinkings and workings, and more accurate knowledge of the seams.

Below this depth of 4,000 feet there are certainly vast stores of fuel which may be recoverable if it is ultimately found possible to carry on operations at such depths. The estimated quantity of such coal is given by the last Commission as 5,239,433,980 tons. There are also unproved areas in Cheshire, Vale of Eden and Solway Firth, Yorkshire and Nottinghamshire, North and South Staffordshire, and under sea coal in

Cumberland and St. Bride's and Carmarthen Bays. It is estimated that the amount of coal which may be expected to be available in these concealed and improved coalfields at depths less that 4,000 feet is 39,483 millions of tons. We thus have the following amounts:

ESTIMATE OF AMOUNT OF AVAILABLE COAL.

	Tons.
Available resources of the Proved Coalfields, one foot thick and upwards, and within 4,000 feet of surface, - - - - -	100,914,668,167
Estimate of Coal below 4,000 feet in Proved Coalfields, - - - - - - -	5,239,433,980
Estimate of Coal within 4,000 feet of surface in Concealed and Unproved Coalfields, -	39,483,000,000
	145,637,102,147

The present annual output of coal is about 230 million tons, so that, if we exclude the 40,000 million tons of the deep and unproved areas, it may be said that at the present rate the coal of this country will last 478 years. Although the supply is so enormous, it should be borne in mind that the best qualities, which are invariably worked first, will be exhausted long before the time named, and it should be remembered also that coal, unlike most commodities, can never be replaced; consequently the greatest care should be taken that none is wasted, or left in such a way that it will eventually become worthless.

The chief coalfields of Great Britain are:

BRITISH COALFIELDS.

South Wales and Monmouthshire.	Lancashire.
Somersetshire and Gloucestershire.	Cheshire.
Forest of Dean.	North Wales.
North Staffordshire.	Yorkshire.
South Staffordshire.	Derby and Nottingham.
Warwickshire.	Northumberland.
Leicestershire.	Cumberland.
Shropshire.	Durham.
	Scotland.
	Ireland.

South Wales Coalfield.—Area, 920 square miles; length from E. to W., 50 miles; breadth from N. to S., 18 miles; thickness

of workable coal, 84 feet; number of seams, 25; probable quantity of available coal (1905), 26,470,000,000 tons.

This extensive coalfield (Fig. 9) lies in the form of a basin in a depression of Old Red Sandstone rocks, by which it is surrounded on all sides except for occasional strips of Millstone Grit and Mountain Limestone.

Being in the form of a basin, the general dip of the measures is toward the centre from every side. The rate is not uniform, the dip from the southern boundary being very great in some places, whereas that from the north is much more gentle. Were it not for the existence of a remarkable anticlinal axis (Fig. 8), stretching in an easterly and westerly direction across the coalfield, the coal seams, especially near the southern boundary of the basin, would quickly become too deep to be worked.

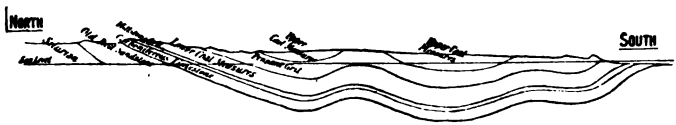


FIG. 8.—Section across South Wales Coalfield from North to South.

The effect of this anticline is to bring up the Coal Measures within easy reach of the surface, thus increasing enormously the available seams of coal, the majority of which are of great value. The possession of twenty-five seams of coal, with an average thickness of over three feet, would in itself be of great value, but when it is remembered that many of these consist of the purest form of fuel known, called **Anthracite**, it is clear that the South Wales coalfield is a valuable one.

The Coal Measures of South Wales may be divided as follows:

Upper Pellengare.—Sandstone, shales and fireclay and several seams of coal.

Pennant Grit.—Hard sandstone and conglomerates, shales, fireclay and a few good coal seams.

Lower Shale Series.—1. Coal seams.
2. Best Coal seams.
3. Coal seams.

The best and greatest number of seams are found in what is known as the Lower Shale Series. This series also contains

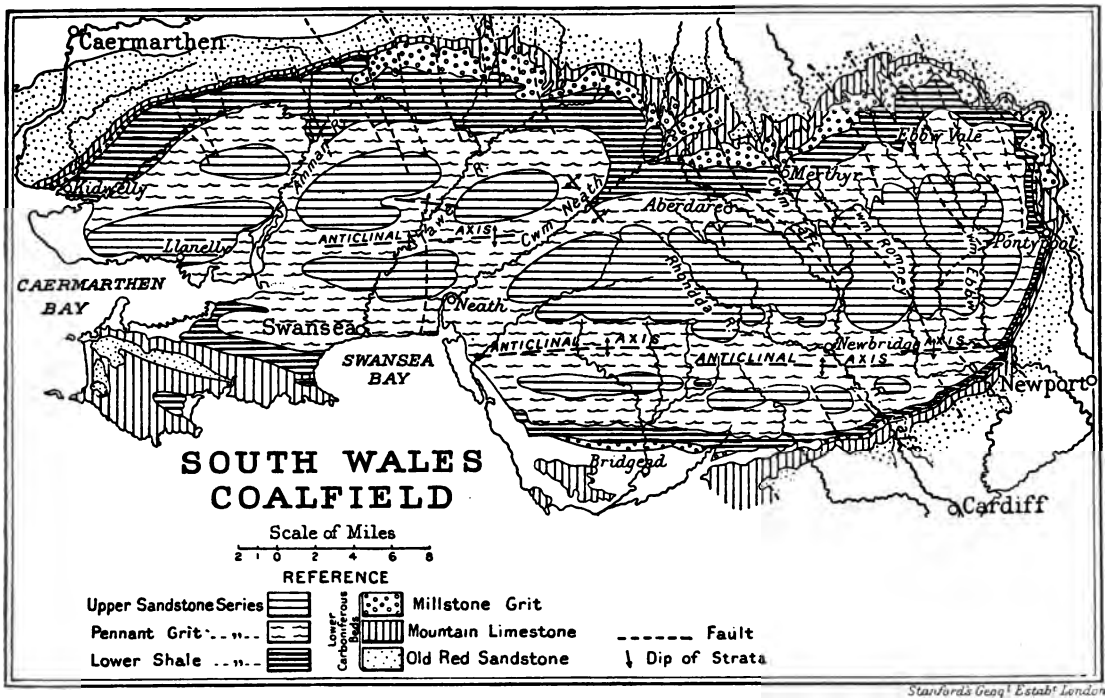

Caermarthen
Kidwelly
Llanelly
CAERMARTHEN BAY
Swansea
SWANSEA BAY
Neath
Aberdare
Merthyr
Ebbw Vale
Pontypool
Newport
Cardiff
Bridgend
ANTICLINAL AXIS
Cwm Nedd
Rhondda
Newbridge
SOUTH WALES COALFIELD
Scale of Miles
2 1 0 2 4 6 8
REFERENCE
Upper Sandstone Series
Pennant Grit
Lower Shale
Lower Carboniferous Beds
Millstone Grit
Mountain Limestone
Old Red Sandstone
Fault
Dip of Strata
Stanford's Geog! Estab! London

FIG. 9.

numerous beds of ironstone, but these are chiefly found near the northern boundary, where many ironworks are situated. The series, which varies in thickness from 450 to 850 feet, may again be split up into three divisions, all containing coal seams, the best of which are found in the middle and lower portions. Above the Lower Shale is found the Pennant Grit Series, consisting chiefly of hard sandstone rocks and conglomerates, some beds of shale and fireclay and a few seams of coal. They vary in thickness from 1,000 to over 3,000 feet. Many of the coal seams are of good quality, but contain larger percentages of sulphur than those of the Lower Shale Series.

As shown by the table (p. 18), the upper Sandstone Series consists of sandstone, shales and fireclay, and contains more coal seams than the Pennant Grit, but not so many as the Lower Shale Series. At Llanelly the thickness of the series is 3,400 feet, and the seams are chiefly anthracite.

Somersetshire and Gloucestershire Coalfield.—Area, 150 square miles; length from north to south, 26 miles; thickness of workable coal, 84 feet; number of workable seams, 40; probable quantity of available coal, 4,198,000,000 tons.

This triangular-shaped coalfield extends from the Mendip Hills in the south to Cromhall in the north. Over a great part of its area, the coalfield is covered by newer formations, as the Trias and Liassic, which lie horizontally upon the Coal Measures, the latter at many points rising at high angles, especially near the boundaries. The field is bounded on all sides by the Carboniferous Limestone, except on the east, where the measures pass under the Oolites. Their extent in this direction is unknown, but it is probable that there is some connection between the seams of these Coal Measures and those lately discovered in Kent.

The Coal Measures of this coalfield, according to Mr. Etheridge, may be arranged in the following sub-divisions:

Upper.	Radstock Group.
„	Farrington Group.
Middle.	The Pennant Group.
Lower.	Bedminster Group.
„	Holcombe Group.

The largest number of seams are to be found in the Lower Group, called also the *Lower Shale Series*, viz., 20 to 35 seams

with an aggregate thickness of 60 feet. The Middle Group consists of a great thickness (1,725 feet) of hard sandstone called the Pennant Rocks, which contain five thin seams of coal. The Upper Group contains 10 seams of coal with a thickness of 24 feet. A great anticlinal axis, running east and west through Kingswood, divides the coalfield into two parts, bringing the lower group to the surface. Owing to the undulating form of the measures the dip is not general over the whole area. North of the River Avon it is north and south, while south of the river it is chiefly from west to east. Along the foot of the Mendip Hills the strata are greatly dislocated in some places, being quite vertical for a distance of 200 or 300 feet, so that a shaft may follow a seam for this distance. At Bristol, in the central part of the field, the measures attain their greatest thickness, and they gradually decrease in the number and thickness of the seams southwards and northwards, towards the boundaries.

Forest of Dean Coalfield.—Area, 34 square miles; thickness of workable coal, 24 feet; number of seams, 8; probable quantity of available coal, 258,533,000 tons.

This interesting coalfield is situated in the county of Gloucester. It is in the form of a basin, resting on the Millstone Grit and Carboniferous Limestone; these measures rising up all round the outcrop of the Coal Measures, like an iron crucible enclosing a quantity of molten metal. Although there is a general dip towards the centre from all sides, the rate is not uniform, being greatest from the eastern boundaries, while the measures extend for a long distance on the western side, being in consequence of greater extent in that direction. The seams vary considerably in thickness and quality.

North Staffordshire Coalfield.—Area, 75 square miles; length from north to south, 13½ miles; breadth from east to west, 10 miles; thickness of workable coal seams, 140 feet; number of seams, 25; probable quantity of available coal, 4,368,050,000 tons.

This coalfield, which is also triangular shaped, is situated in the north of the county of Staffordshire, and has a great number of extremely good coal seams, as well as several seams of ironstone, which occur in conjunction with some of the coal seams. The apex is toward the north; on the western side are the New Red Sandstone and Permian rocks; on the east the

Millstone Grit; on the south the Coal Measures dip beneath the Permians, these beds also running right up into the centre of the field near Newcastle-under-Lyme, along a great fault. Along the central and northern portions of the field the strata have been thrown into a double fold along synclinal and anticlinal axes. The synclinal axis takes a direction from the neighbourhood of Biddulph in the north to Newcastle-under-Lyme; the anticlinal is on the western boundary, and causes a sharp reversal of the dip through Silverdale. The extreme western boundary is the Red Rock Fault.

The North Staffordshire Coal Measures may be divided as follows:

		Thickness.
Upper.	Sandstone, thick beds of clay, thin coal seams and a bed of limestone, - - - - - -	1,000 feet.
Middle.	Sandstone, shales, with ironstones and about 40 coal seams, - -	4,000 feet.
Lower.	Shales, thin coal seams, red ironstone, - - - - - -	1,000 feet.
	Millstone Grit.	

The coal seams of North Staffordshire are of good quality and thickness. The occurrence of valuable bands of ironstone (black-band ironstone) (Fig. 10) in proximity to the coal makes this field one of the most important in the country, and here ironstone beds often form the roof of the seams, and are from 1 to 3 feet in thickness. In the neighbourhood of Trentham and other districts, coal is worked beneath the later formations, and a vast store of coal is here still untouched.

South Staffordshire Coalfield.—Area, 93 square miles; length, north to south 22 miles, east to west 8 miles; thickness of workable coal, 50 feet; number of seams, 14; probable quantity of available coal, 1,415,448,000 tons.

This coalfield stretches from Brereton and Cannock Chase on the north to the Clent Hills on the south, and covers a portion of East Worcestershire. On either side it is bounded by downthrow faults, which bring the Permian and New Red Sandstone rocks into juxtaposition with the Coal Measures. In the centre of the coalfield rise the Silurian beds, forming the isolated hills of Dudley and Sedgeley. At Hamstead and Sandwell Park, which are both just outside the coalfield

proper, mining operations have been carried on recently, the mines here being below the Permians.

In the neighbourhood of Dudley there are six workable seams, with a total thickness of 65 feet. These include the famous ten-yard seam or "thick coal," which is 30 feet thick, and the whole of the coal is of extremely good quality. At Cannock Chase the number of seams is 14, with a total thickness of 57 feet. The dip of the beds in the north is generally from east to west. The beds of interlying strata thin out in a remarkable manner from north to south. The 30-ft. Dudley seam splits up passing north, into nine distinct seams, with a total thickness of just 30 feet, the thickness of beds and seams being 420 feet.

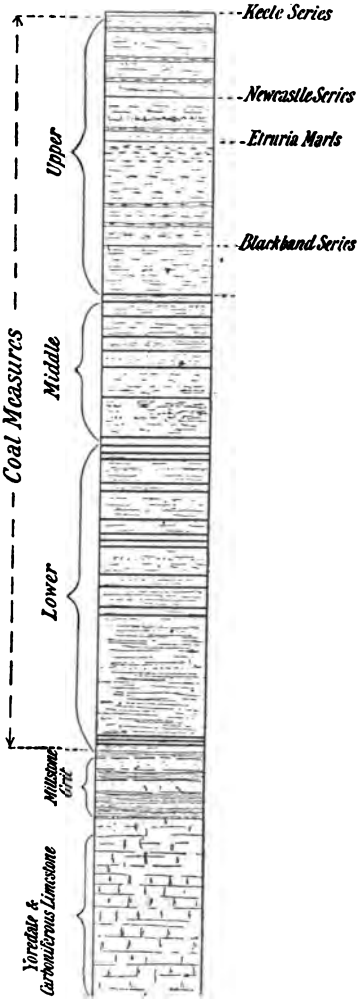


FIG. 10.—Section of Strata at Newcastle, North Staffordshire Coalfield.

Warwickshire Coalfield.—Area, 30 square miles; length from north-west to south-east, 15 miles; thickness of workable coal, 30 feet; number of seams, 5; probable quantity of available coal, 1,126,982,000 tons.

This coalfield, where it is exposed, stretches from Polesworth

in the north-west to Exhall in the south-east, a distance of 15 miles. It is bounded by the Trias rocks on all sides except the south, where the measures pass below a large tract of Permians which stretch from Bexterley to Coventry, an area of 90 square miles, and here at a depth of not more than 2,500 feet there are many valuable seams of coal. It is in this direction that the development of the field is tending. The strata dip towards the west, except at the northern end, where they form a trough with a dip towards the east.

Like the seams in the northern portion of the South Staffordshire coalfield, the five workable seams are separated by 120 feet of shales and sandstones, which gradually decrease until near Coventry in the south, where they form one large bed 26 feet in thickness.

Lancashire and Cheshire Coalfield.—Area, 217 square miles; length from east to west, 32 miles; average breadth, north to south, 16 miles; thickness of workable coal, 62 feet; number of seams over two feet, 18; probable quantity of available coal, 4,530,340,000 tons.

This large and important coalfield (Fig. 12) stretches from Knowsley in the west to Dukinfield in the east, and from Darwen in the north to Poynton in the south. There are also isolated areas near Liverpool, Burnley, etc. The coalfield is bounded along the north and east by the Millstone Grit, on the south and west by the Permian and Triassic formations. The dip of the measures is generally towards the south. Large faults traverse the field in directions ranging N.N.W. to S.S.E. A large fault on the extreme western boundary throws down the New Red Sandstone a distance of 700 yards, while another in the east, known as the Irwell Valley Fault (Fig. 11), has a throw of 1,000 yards, bringing in the New Red Sandstone. Other important faults are the Shevington Fault, the Great Haigh Fault, the Cannel Fault of Ince in the west, and a large

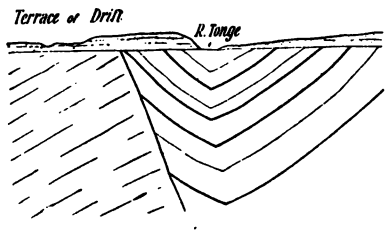


FIG. 11.—Irwell Valley Fault of 1,000 yards, Lancashire Coalfield.

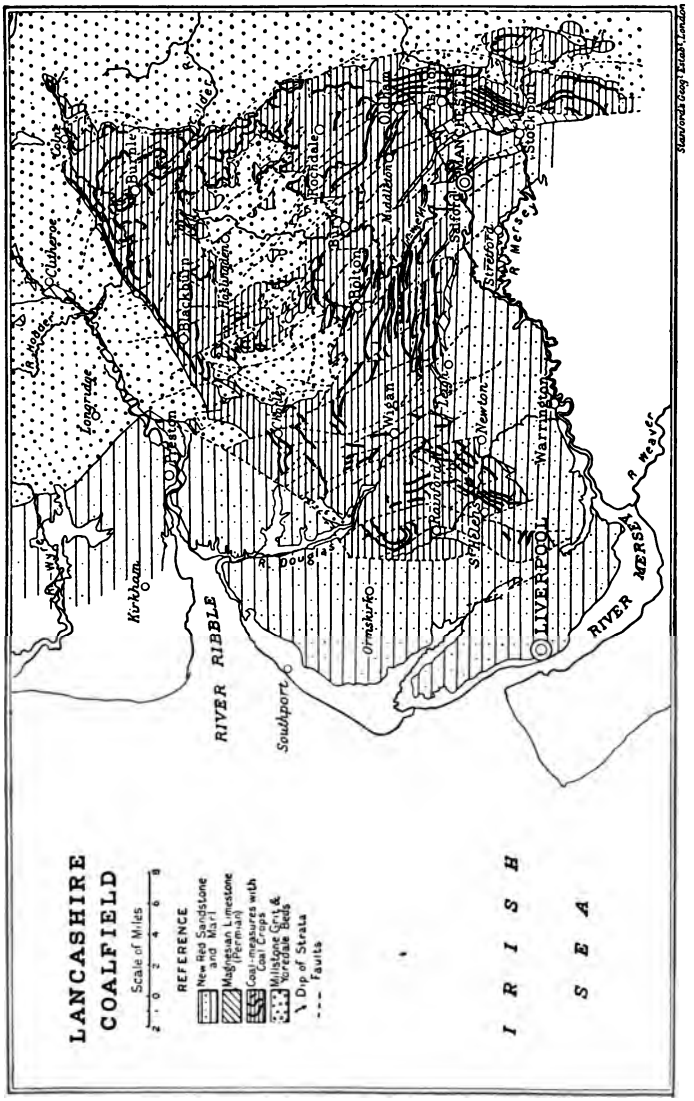

LANCASHIRE
COALFIELD
Scale of Miles
REFERENCE
New Red Sandstone and Marl
Magnesian Limestone (Permian)
Coal-measures with Coal Seams
Millstone Grit & Yoredale Beds
Dip of Strata
Faults
I R I S H
S E A
RIVER RIBBLE
RIVER MERSEY
Kirkham
Preston
Blackburn
Burnley
Todmorden
Rochdale
Bolton
Wigan
Manchester
Oldham
Stockport
Altrincham
Stretford
Warrington
Newton
St Helens
Ormskirk
Southport
LIVERPOOL
Formby
R. Weaver
Widnes
Runcorn
Clitheroe
Longridge
Colne
Skipton
Haslingden
Ramsbottom
Leigh
Eccles
Salford
Barrow
Ince
Prescot
Knowsley
Walton
Bootle
Waterloo
Crosby
Ainsdale
Lytham
Fleetwood
Garstang
Chorley
Wyre
Ribble
Douglas
Irwell
Mersey
Goyt
Etherow
Tame
Irk
Medlock
Irwell
Croal
Roch
Irk
Irwell
Douglas
Ribble
Wyre
Lune
Hodder
Calder
Brun
Ribble
Douglas
Irwell
Mersey
Goyt
Etherow
Tame
Irk
Medlock
Irwell
Croal
Roch
Irk
Irwell
Douglas
Ribble
Wyre
Lune
Hodder
Calder
Brun

FIG. 12.

fault near Manchester with a throw of 400 yards. All these dislocations appear to have taken place after the formation of the New Red Sandstone.

The Lancashire Coal Measures may be divided as follows:

	Thickness.
Upper.—Shales, sandstones, limestones, a bed of black-band ironstone; below these sandstones, shales and thin coal seams,	1,600 to 2,000 feet.
Middle.—From the Worsley Four-feet to the Arley mine. Shales, sandstones, etc., with the best coal seams, of thicknesses varying from 2 to 7 or 8 feet, - -	3,000 to 4,000 „
Lower or *Gannister Beds.*—Flags, shales and thin coal seams, - - - - -	1,400 to 2,000 „
Millstone Grit.—Thin coal seams in lower part, - - - - - - -	3,500 to 5,000 „
Yoredale Rocks, - - - - - -	2,000 to 4,000 „

The Upper Coal Measures.—The sixteen or seventeen seams in the Upper Coal Measures are, as a rule, very thin and are not worked to any great extent. As will be seen, the chief seams are in the Middle Coal Measures.

The Middle Coal Measures.—The *Worsley Four-feet* is the top mine of the middle series, and is worked in the neighbourhood of Leigh, where the middle series is immediately overlain by the Permians. In this district, and in fact throughout the whole area extending from Ashton and Newton in the west to Worsley in the east, shafts are now being sunk through the New Red Sandstone and Permian beds. The thicknesses of these beds vary, but as the Upper Coal Measures are as a rule missing, the seams of the Middle Measures are found at a reasonable depth. In this same district the greatest number of workable seams are found. The best are probably the *Arley, Three-quarters, Yard, Trencherbone, White and Black* and *Crumbourke.* The Arley, called also the *Royley* and *Little Delf*, which is the lowest seam of the Middle Coal Measures, is the most consistent, and at present the most valuable seam in the coalfield.

The Lower Coal Measures.—Below the Arley Mine are several thin, and oftentimes inferior seams of coal, which are worked in the neighbourhood of Upholland in the centre of the field, and at Dukinfield and Oldham in the east. At Dukinfield is

the Astley Deep Pit, where the Black Mine is worked at a depth of 687 yards.

The Mountain Mines.—Coal seams known by this name are found in the northern and eastern portions in the lower coal measures. At Burnley, Crompton, Rochdale, Darwen, Turton, etc., they are of good quality and yield strong coke. The two seams, *Upper Mountain Mine* and *Gannister* or *Lower Mountain Mine* are the chief ones worked, the former being 14 to 16 inches in thickness and the latter 18 to 30 inches.

North Wales Coalfield.—Area, 82 square miles; length 38 miles; greatest breadth, 4 miles; thickness of workable coal, 35 feet; number of seams, 7; probable quantity of available coal, 1,736,000,000 tons.

This is a long, narrow coalfield, stretching along the estuary of the Dee and covering portions of the counties of Flint and Denbigh. The field is bounded on the north and north-east by the Irish Sea and the estuary of the Dee, on the east and south-east by the New Red Sandstone, on the west and south-west by the Permians. The Coal Measures are overlain by the Permian Rocks in the south and the New Red Sandstone in the north. The general dip is towards the north, and the Coal Measures pass under the sea and the estuary of the river Dee, where coal is at present being worked. Many faults occur, especially in the Flintshire area.

The Coal Measures of the North Wales coalfield may be divided as follows:

1. *Upper Series*, consisting of red and grey sandstones and clays, a few thin coal seams.
2. *Middle Series*, the true coal-bearing strata, contains many excellent seams of coal, some of great thickness.
3. *Lower Series*, contains several thin seams and beds of ironstone.

The seams are of good quality, and some of them of great thickness. The Cannel Coal is of good quality and great thickness, and is similar to the famous Wigan Cannel. Valuable beds of Ironstone are also worked in this field.

Yorkshire, Derbyshire and Nottinghamshire Coalfield.—Area, 760 square miles; length from north to south, 68 miles; breadth varies from 5 to 20 miles; thickness of workable coal (including, say, 4,000,000,000 in concealed area), 20,498,731,000 tons.

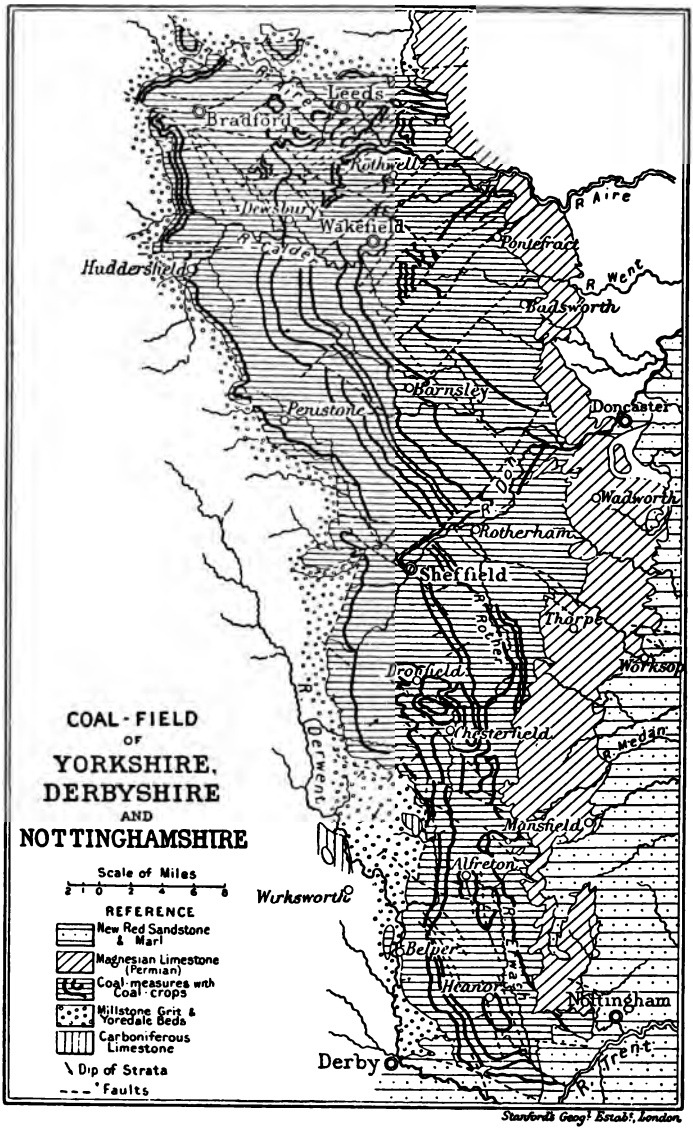

Leeds
Bradford
Rothwell
Dewsbury
Wakefield
Huddersfield
Pontefract
Badsworth
Barnsley
Penistone
Doncaster
Wadworth
Rotherham
Sheffield
Thorpe
Worksop
Brookfield
Chesterfield
Mansfield
Alfreton
Worksworth
Belper
Heanor
Nottingham
Derby
R. Aire
R. Calder
R. Went
R. Don
R. Rother
R. Derwent
R. Trent
COAL-FIELD
OF
YORKSHIRE,
DERBYSHIRE
AND
NOTTINGHAMSHIRE
Scale of Miles
2 1 0 2 4 6 8
REFERENCE
New Red Sandstone & Marl
Magnesian Limestone (Permian)
Coal-measures with Coal-crops
Millstone Grit & Yoredale Beds
Carboniferous Limestone
Dip of Strata
Faults
Stanford's Geog! Estab!, London.

FIG. 13.

This extensive coalfield (Fig. 13) stretches over a large portion of the counties of Yorkshire, Derbyshire and Nottinghamshire, and is the largest in extent in England. It is bounded on the north and west by the Millstone Grit and Yoredale beds; on the east by the Magnesian Limestone beds of the Permians, which are again overlain by the New Red Sandstone; and in the south by the New Red Sandstone. The dip of the measures is towards the east, except in the north, near Leeds, where the outcrops bend round to the east considerably, making the dip change to south. Along the centre of the field, however, there is here and there a roll of the strata producing a western dip. The field is not greatly affected by faults.

The measures may be divided as follows:

Permians, - -	700 feet.
Middle.—Containing shales and the best coal seams, - -	1,600 „
Lower or *Gannister Series.*—Shales and sandstones with two coal seams, -	1,000 „
Millstone Grit and Yoredales.	

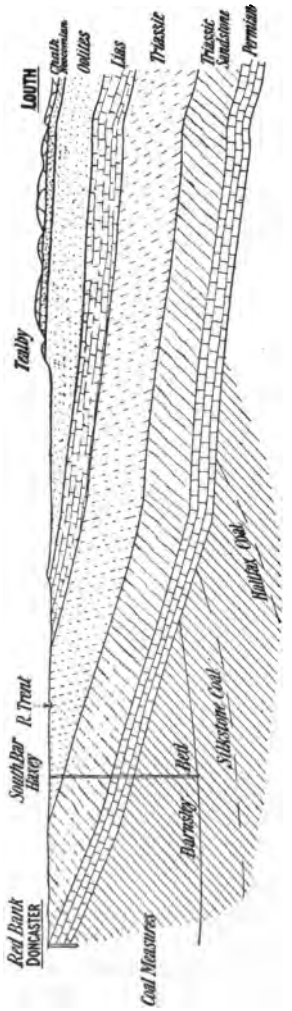


FIG. 14.—Section of Strata from Doncaster to Louth in the Yorkshire, Derbyshire, and Nottinghamshire Coalfield.

The chief coal seams are: The *Silkstone* (the Arley of Lancashire), *Parkgate*, *Flockton*, *Barnsley*, *Warren House* and *Top Hard*, in the Yorkshire district, and the *Kilburn*, *Black*

Shale and *Top Hard* seams in the Derby and Nottinghamshire district. The Kilburn, Top Hard and Silkstone seams produce remarkably good coal, called *Splint coal.* A large area of coal is now being worked beyond Doncaster (Fig. 14) and the eastern boundary of the visible field, in the neighbourhood of Worksop, Mansfield and Nottingham. Here the valuable *Top Hard* and other seams have been found below the Secondary rocks, and mining is rapidly developing.

Northumberland and Durham Coalfield.—Area, 460 square miles; length from north to south, 50 miles; breadth, 23 miles at widest part; thickness of workable coal, 46 feet; number of seams, 16 to 20; probable available quantity of coal, 2,867,307,000 tons.

This old and important coalfield (Fig. 15) stretches over the greater portion of the counties of Northumberland and Durham. It extends from the river Coquet on the north to Staindrop (on the north of the Tees) in the south; and from Ponteland and Wolsingham in the west to the North Sea on the east. It is bounded on the east by the North Sea and the Magnesian Limestone; on the south by the Magnesian Limestone and Millstone Grit; on the west by the Millstone Grit. The coalfield runs out to an apex in the north. Large quantities of coal, however, are worked beneath the Permian rocks in Durham, and a few inferior seams are worked in Northumberland below the Millstone Grit. Coal is also worked beneath the sea at Blythe, Monk Wearmouth, Whitburn, and Seaham. The largest fault is the "ninety-fathom fault," but the coalfield is much broken up by a large number of smaller dislocations.

The Coal Measures may be divided as follows:

		Thickness.
1. *Upper.*	Shales and thin coal seams with bands of ironstone, - - -	900 feet.
2. *Middle.*	- - - - - - - -	2,000 „
3. *Lower.*	With two thin coal seams, Millstone Grit and Yoredales. -	150 „

In the Newcastle district, the best seam is the highest workable one—the High Main—and is five or six feet thick. The most consistent seam is probably the Low Main, which is an excellent house and coking coal, although northwards from Newcastle its nature changes and it becomes a good steam coal.

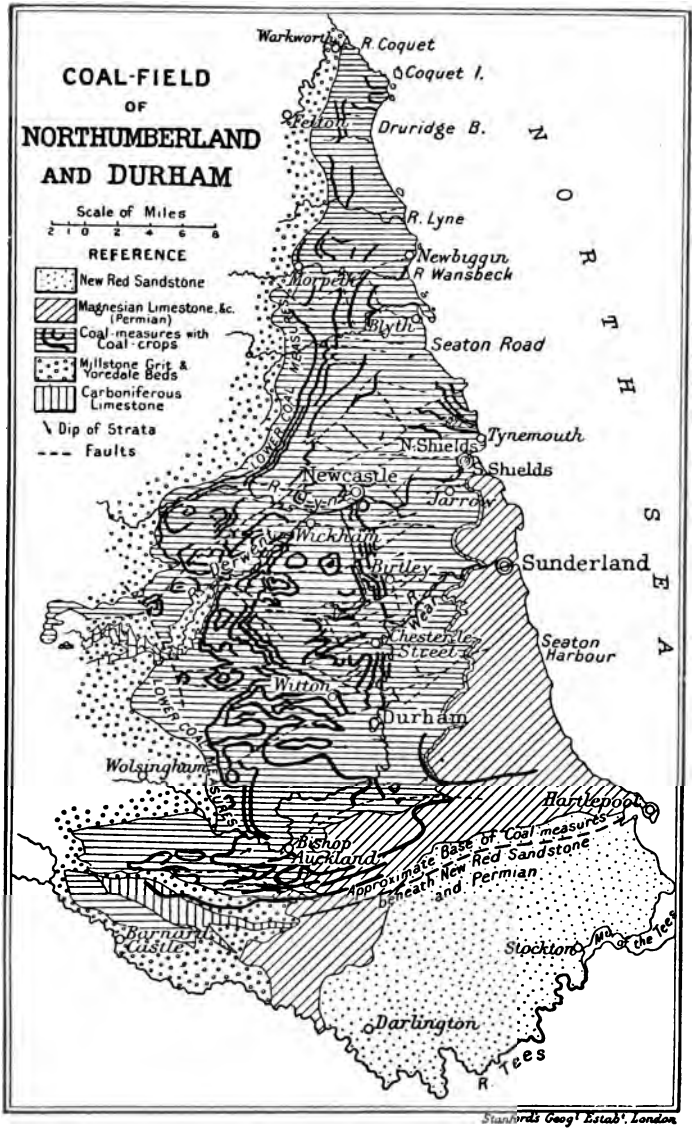

COAL-FIELD
OF
NORTHUMBERLAND
AND DURHAM
Scale of Miles
2 1 0 2 4 6 8
REFERENCE
New Red Sandstone
Magnesian Limestone, &c. (Permian)
Coal-measures with Coal-crops
Millstone Grit & Yoredale Beds
Carboniferous Limestone
Dip of Strata
Faults
Warkworth
R. Coquet
Coquet I.
Felton
Druridge B.
R. Lyne
Newbiggin
R Wansbeck
Morpeth
Blyth
Seaton Road
Tynemouth
N. Shields
Shields
Newcastle
Jarrow
Wickham
Burley
Sunderland
Chester-le-Street
Seaton Harbour
Witton
Durham
Wolsingham
Hartlepool
Bishop Auckland
Approximate Base of Coal-measures beneath New Red Sandstone and Permian
Barnard Castle
Stockton
Mouth of the Tees
Darlington
Tees
R
N O R T H S E A
Stanfords Geog! Estab! London

FIG. 15.

Coalfields of Scotland.—The coalfields of Scotland are found in the great valley along the estuaries of the Clyde and Forth. Coal is worked not only in the Coal Measures proper, but in the beds akin to the Yoredales and Carboniferous Limestones. Great upheavals of older rocks, such as the Calciferous Sandstone series and volcanic rocks, separate one coalfield from another, and they may be divided as follows :

1. *Eastern Basin.*—This includes the coalfields of Midlothian, Haddington and Fife, and the coal beneath the Forth.

2. *Central Basin.*—This includes the Clyde and Clackmannan fields, with the detached fields of Lesmahagow.

3. *Western Basin.*—This includes the Ayrshire and Dumfriesshire fields.

Eastern Basin.—The Midlothian and Haddington coal basin occurs in the form of a double trough, the deeper part of

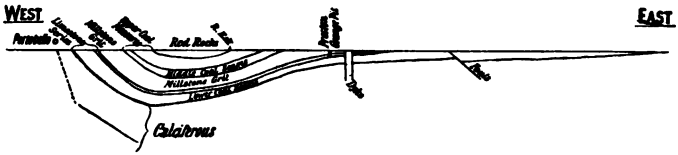


FIG. 16.—Section of Strata at Portobello, in Midlothian Coalfield, showing Calciferous Sandstone.

which lies in Edinburghshire on the west and the shallower in Haddington on the east. East of Edinburgh the northern boundary is formed by the Firth of Forth, but the seams and their overlying strata pass beneath the river. The Fifeshire basin is to the north of the Firth of Forth, and is no doubt connected with the above-named field. Its seams are few, but produce good gas and steam coal.

Central Basin.—The Clyde basin coalfield is the most important portion of this field. It stretches across portions of Renfrewshire, Dumbartonshire, Stirlingshire, and the whole of Lanarkshire. Ten to twelve seams of good workable coal, together with valuable seams of clay and Black-band ironstone, are also found, besides a bed of good cannel. The lowest workable seam is the *Hurlet*, which is five feet thick. Clackmannan and Lesmahagow are detached coalfields, the latter in the south of Lanarkshire. Here about six coal seams,

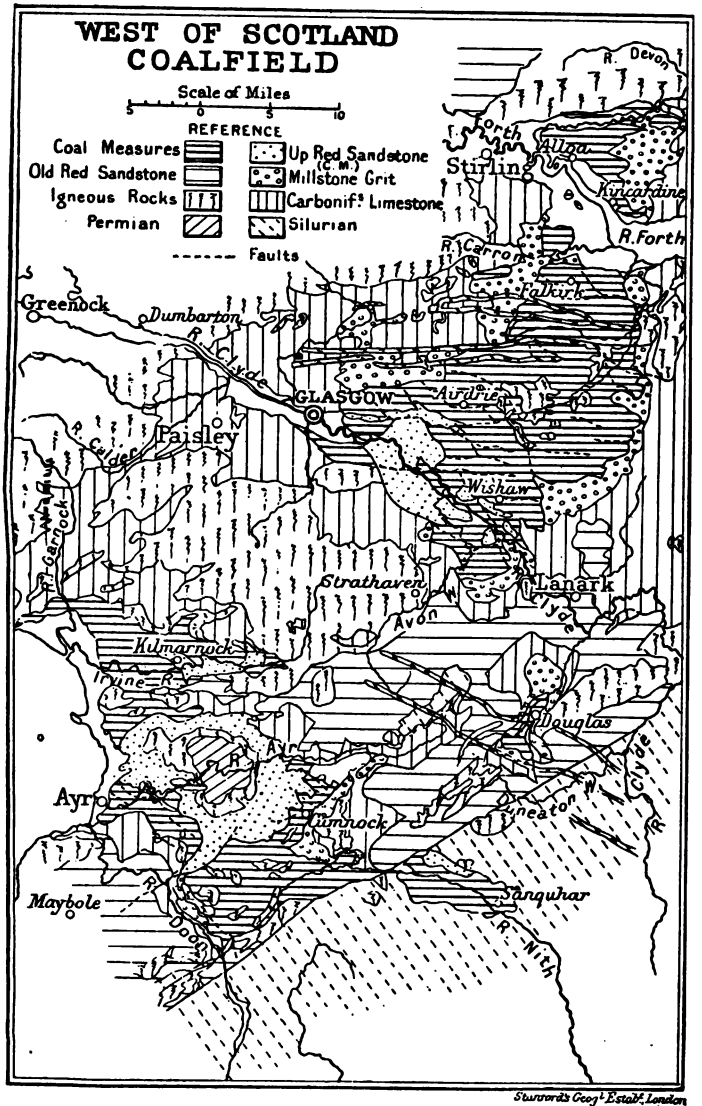

WEST OF SCOTLAND
COALFIELD
Scale of Miles
5 0 5 10
REFERENCE
Coal Measures
Old Red Sandstone
Igneous Rocks
Permian
Up Red Sandstone
(C. M.)
Millstone Grit
Carboniferous Limestone
Silurian
Faults
Greenock
Dumbarton
R. Clyde
GLASGOW
Airdrie
Paisley
R. Cart
R. Garnock
Wishaw
Strathaven
Lanark
R. Clyde
Avon
Kilmarnock
Irvine R.
Douglas
Ayr
Dalmellington
Cumnock
Dyneaton
Maybole
Sanquhar
R. Nith
R. Devon
Stirling
Alloa
Kincardine
R. Forth
R. Carron
Falkirk
Stanford's Geog.l Estab.t London

FIG. 17.

C.M. C

together with Black-band and clay ironstone, are found, and are now being developed.

Western Basin.—The Ayrshire coalfield (Fig. 17) stretches along the Irish Sea from Ardrossan to the mouth of the Doon. Large quantities of coal are shipped from the neighbouring seaports, but on account of the sudden intrusion of volcanic rocks, the areas are uncertain. There are five workable seams, with a total thickness of 20 feet. In Dumfriesshire, two small basins —Canonbie and Sanquhar—produce some coal, the latter being most productive, with seven seams over three feet thick and a total thickness of 36 feet of coal.

The total area of the Scottish coalfields may be given as 1,547 square miles, with a probable available supply of 15,681,456,000 tons.

Questions on Chapter II.

1. Explain the terms Conformability and Unconformability.
2. What is the supposed origin of coal seams, and why are the different seams found to overlie each other?
3. Describe the manner in which it is considered that coalfields have been formed.
4. What are the Synclines and Anticlines?
5. What depth has been assumed by the Royal Coal Commissions of past years as the probable limit of working coal mines in this country? What estimate has been made of coal below that depth?
6. What are the estimated resources of the proved, concealed, and unproved coalfields of this country, and what considerations are likely to affect these computations?
7. Name the most important coal areas in the British Isles.
8. Describe the Yorkshire, Derbyshire and Nottinghamshire coalfield, noticing points of geological and technical mining interest. (1897.)
9. Give an account of the Lancashire and Cheshire coalfield, noticing points of technical and mining interest. (1896.)
10. Give an account of the South Wales coalfield, noticing such points in geological structure as are of special mining interest.

CHAPTER III.

COAL.

Formation of Coal.—Coal is composed of the remains of vegetable matter—plants and trees—the growth of a former age. This vegetable matter has undergone great changes in its structure and composition owing to the great pressure exerted by the strata which have afterwards been deposited upon it, the chemical action within it, and the enormous time during which these agencies have been at work. This ancient vegetation grew on low swamps and flood plains near the mouths of rivers and on the delta deposits at their mouths. These swamps were, owing to subsidence of the earth's crust, afterwards buried under beds of sand and shale deposited in the water which covered them. Alternate elevation and subsidence seems to have occurred, and conditions suitable for plant growth again prevailed after the sand and shale had been deposited. When numerous coal seams occur one above another, this process must have been repeated time after time—each coal seam representing the period when vegetation flourished, and the interlying strata, periods during which water completely covered the land and deposition of sand or other deposits took place.

Fossils.—The fossils of the Coal Measures are important, as it is chiefly by a consideration of their number, kind and situation, that the mode of the formation of the various seams and the interlying strata can be determined.

Flora.—The Flora of the Coal Measures consist of *Ferns* and other plants, which are often preserved in great perfection.

The most common plants are: *Pecopteris*, *Alethopteris* (Fig. 18 *b*), *Neuropteris* (Fig. 18 *c*), *Sphenopteris* (Fig. 18 *d*),

Odontopteris. The Horse-tails (*Equisetaceae*) are represented by Calamites, the foliage of which *Asterophyllites* and *Annularia* are also well-known fossils. Other fossils include such plants as the *Lepidodendron*, *Lepidophloios*, *Bothrodendron*, *Sigillaria*, with the roots *Stigmaria* (Fig. 18 *a*) and *Stigmariopsis*; the *Cycads*, the *Coniferae* and the *Cordaites.*

Fauna.—If the flora of the Coal Measures serve to prove the vegetable origin of the seams, the fauna no less prove the marine origin of the series of shales and sandstones which occur between one bed of coal and another. It is true that marine forms of animal remains are most abundant in the lower half of the Coal Measures, but even in the upper part, although some forms have entirely disappeared, a large number of fossil fauna are found.

The chief marine fauna of the Coal Measures are the *Spirifera*, *Producta* and *Lingula*; *Nautilus* (Fig. 18 *e*) and *Goniatites.*

Other animal remains in the Coal Measures are *Anthracosia*, *Anthracoptera*, *Amblypterus.* The salamander-like animals, known as the *Labyrinthodonts*, appeared in Carboniferous times, of which the *Archigosaurus* is the most important type.

Composition of Coal.—The chemical analysis of coal shows it to contain the same elements as wood. It consists mainly of carbon, and compounds of carbon and hydrogen. Plants and other vegetation consist of oxygen, hydrogen, carbon and nitrogen, in various amounts. After being buried by strata, the vegetable matter underwent chemical changes. Various gases, such as carburetted hydrogen, or firedamp (CH_4), carbonic acid gas (CO_2) and water were given off, leaving a greater percentage of carbon and a smaller amount of the other elements. Owing to the enormous pressure and heat, this chemical change has continued for long ages, compressing and hardening the seams, until they have assumed their present mineralised condition. The following tables, giving the percentages of the elements found in wood and different varieties of coal, will show that all are made up of the same elements, but that there is a gradual increase of carbon and a consequent decrease of all other elements as we pass to the purest form of coal, viz., **Anthracite.**

a *b* *c* *d* *e* *f*

FIG. 18.—Fossils of the Coal Measures.

COMPOSITION OF COAL (ANDRÉ).

TABLE I.

Substance.	Specific Gravity.	Carbon.	Hydrogen.	Oxygen and Nitrogen.
Wood, - - - -	0·91	49·00	6·25	44·75
Peat, - - - - -	0·99	59·30	6·52	34·18
Lignite, - - - -	1·25	72·37	5·18	22·45
Cannel, - - - -	1·27	80·37	5·83	13·80
Bituminous, - - -	1·30	86·17	5·21	8·62
Semi-Bituminous, - -	1·37	90·00	4·75	5·25
Anthracite, - - -	1·50	92·50	3·75	3·75

COMPOSITION OF COAL (TONGE).

TABLE II.

Fuel.	Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Ash.	Available and Disposable Hydrogen.
Lignite, non-caking, -	75·50	5·00	13·50	3·00	3·00	3·30
Cannel, Wigan, caking,	80·50	6·00	8·50	2·00	3·00	4·94
Bituminous, caking, -	85·00	5·20	8·2	0·60	1·00	5·0
Semi-Bituminous, non-caking,	90·00	4·17	2·53	1·72	1·58	3·86
Anthracite, non-caking,	93·50	1·50	2·6 O. & N.		2·40	1·2

It will be seen from the above tables that all **Organic Fuels** consist chiefly of carbon, hydrogen, oxygen and nitrogen, together with a greater or smaller quantity of *inorganic matter* which is called *Ash.*

Now, in order to understand clearly the basis on which the varieties of coals are divided into different classes, it will be necessary to learn a little about the chief elements entering into their composition.

Oxygen does not occur in a free state in a fuel, but only in combination with other constituents, and no part of the fuel which is already *oxidised* will be capable of developing any further heat. In order to estimate from its chemical composition

the value of a fuel as a heat producer, it will be necessary to allow for a certain amount of carbon and hydrogen, which will be required to combine with the oxygen already present in the coal. If the oxygen combines with the hydrogen, water is formed; if with the carbon, then carbon dioxide will be formed. As a rule, the deduction is made from the hydrogen, the result being that probably half of the hydrogen is used up in this way, leaving only a small quantity of *disposable* or *available* hydrogen to assist in the combustion of the fuel by its combination with the oxygen of the atmosphere.

Carbon is the chief heat-producing element in coal; consequently the heating or calorific power depends upon the percentage of carbon present. The *Calorific Power* of a fuel is represented by the quantity of heat produced in completely burning one part by weight of the fuel.

Hydrogen and **Oxygen** when combined to form *water* or moisture are objectionable, as this not only reduces the amount of available hydrogen, but causes a considerable amount of the calorific power of the coal to be expended uselessly in driving off the water.

Sulphur, in iron pyrites, is also a drawback, being of no assistance either as a heat or gas producer.

Ash, which consists generally of silica, lime, alumina and oxide of iron, is also worthless, being quite incombustible.

Caking and Non-Caking Coals.—In Table No. II. (p. 38) it will be seen that the quantity of available or disposable hydrogen increases to a certain point, the amount of carbon also increasing similarly. But it is found that these coals do not **cake**, that is to say, the particles do not stick together in a plastic mass when heated either in open grates or closed retorts. Consequently, these coals are placed in the **non-caking** class. As the available hydrogen increases beyond this point, it is found that these coals possess the property of **caking** together when heated, and forming a mass of coke when heated in a closed retort. This **coke** is the residue of carbon left after all the other elements have been driven off either in the form of **coal gas** or **coal tar**. These coals may be called the **caking class**. It will also be seen from the above table that some coals, rich in carbon, but with a smaller quantity of available hydrogen, do not possess this property, so we are led to the conclusion that the caking power of a coal depends, not upon the amount

of carbon contained in it, but upon the quantity of available hydrogen.

Varieties of Coal.—The chief mode of classification of coals is as follows: Gaseous, Bituminous, Semi-Bituminous, Anthracitous.

Gaseous—This is the name generally given to those coals which give off large quantities of volatile gas when heated. This class contains varieties of both caking and non-caking properties; coals such as **Cannel, Hard Coal, Brown Coal** or **Lignite.** They are generally brownish black in colour, and when ground to powder are quite brown. They are free burning coals, giving a long candlelight flame. Their structure as a rule is conchoidal. Cannel Coal does not cake on heating, and retains its ordinary structure.

The famous Abram Cannel gives per ton the following results: 14,111 cubic feet of 39 candle power gas, 7 cwts. of good coke and a large percentage of valuable residuals.

The percentage of ash and sulphur is generally large.

The calorific power, when free from water and ash, is from 8,000 to 8,500.

Bituminous.—The Bituminous Coals contain more carbon and disposable hydrogen than the gaseous coals, but less oxygen. They include both caking and non-caking varieties. Their calorific power is considerably higher than the last-named class, and they give off a good percentage of volatile gas.

There are three distinct varieties of Bituminous Coals, viz.: **Clear Burning, Flaming, Fuliginous.**

1. **The Clear Burning Coals** are similar in structure and appearance to the gaseous coals. They are generally very friable, and break up into small regular lumps. The flame from these coals is generally clear, and not so long as from cannel. Although the percentage of gas obtained from this coal is not so high as from other varieties, the large quantity of coke which is obtained when this coal is burnt makes a clear burning coal a valuable fuel for manufacturing purposes.

2. **The Flaming Coals.**—These are the true caking coals. Their structure may be said to be platey; they are very friable, and are known as *soft coals.* When heated the particles fuse together, forming a spongy mass of tarry substance, through which the gas escapes, and, when observed in an open

grate, the mass is seen to spurt out intermittently as a narrow tongue of flame, followed by a small but dense stream of unkindled smoke. The result of this caking is that larger quantities of excellent coke are obtained from this variety of Bituminous Coal.

3. **The Fuliginous Coals**, so called because of the sooty character of their flame, are also rich in volatile constituents, the gas obtained being of a good quality, and large in amount. Their caking property is not so marked as in the Flaming Coals, and consequently the coke is of a poor quality, but the other residuals are greatly valued.

Semi-Bituminous.—As the Semi-Bituminous Coal seams are found below the Bituminous and Gaseous seams, we know that they have lain longer in the earth, and have therefore been subjected to greater heat and pressure through a longer period. Consequently, as is seen from the table (p. 38), semi-bituminous coals contain a smaller proportion of volatile matter and a greater proportion of carbon. The amount of carbon is sometimes as high as 92 per cent., and these coals gradually pass into true anthracite. They are generally a dull black colour, but harder than the coals hitherto described. The flame is shorter, is sometimes entirely absent, and when burnt in a good draught the flames emit very little smoke. They are chiefly used as **Steam Coals**, the calorific power being over 9,000. They are non-caking, and are sometimes called **Free Burning Coals**.

Anthracite.—Anthracite is coal in its most altered form. Found deeper than the Semi-Bituminous, it has undergone a greater change, the proportion of carbon being increased, and that of the volatile matters in consequence diminished. It is a brilliant black in colour, and has the appearance of being more completely mineralised. Its structure is homogeneous, and it often flies to pieces on being heated. More heat is required to ignite it than is the case with all other varieties, but once lit, the heat is intense, being much greater than that given off by any other coal. It burns without flame, smoke or smell. It is a non-caking coal, the amount of disposable hydrogen being very small; it leaves from 85 to 94 per cent. of fixed carbon, but this is of no value as coke. Anthracite is chiefly used where intense heat is required and a good draught is obtainable, and where the absence of smoke is a

necessity. Consequently, it is in great demand for use in battleships and other ocean-going steamers.

The washing of coal and the manufacture of briquettes may be said to have increased the varieties of coal, but as the "small" of many different classes of coal may be turned into briquettes, we do not propose to discuss the subject under the head of "Composition of Coal," but under that of "The Preparation of Coal for the Market" (p. 327).

The specific gravity of coal varies from 1·25 to 1·51.

Coke.—Coke consists of the residue of carbon and ash, which remains after all the hydro-carbons, oxygen, nitrogen and water have been driven off from any variety of coal.

We have shown that although most coals produce coke, it is only from the caking variety of the Bituminous coal that the best coke can be obtained. There should be at least 4·5 per cent. of disposable hydrogen if a coal is to yield good coke.

If we take an ordinary clay tobacco pipe with a long stem, fill the head with powdered bituminous coal, and cover the top with clay, so as to shut out the air, and apply heat by means of a Bunsen burner to the head, the decomposition of the coal will take place. The coal splits up, the gaseous products, such as the lighter hydro-carbons, being emitted at the end of the stem, where they will burn if a light is applied. When the driving off of the gas is completed and the clay removed, a mass of brittle and more or less spongy-looking carbon is found, which contains also certain quantities of inorganic matter called ash. This is **Coke**, and may be called the charcoal of coal. Besides the lighter hydro-carbons already mentioned, however, other volatile compounds, the heavier hydro-carbons, etc., are produced, and these are collected when this process is conducted on a large scale, as in gas making, and produce what are known as tar and ammoniacal liquor. From these many useful substances called **bye-products** are obtained.

Questions on Chapter III.

1. Say what you know of the way in which coal has been formed.

2. What are the most common fossils found in the Coal Measures?

3. What reasons have been given for assuming that coal is of vegetable origin?

4. What are the constituents ordinarily determined in coal by analysis? Give their relative importance in determining its value. (1898.)

5. What constitutes the essential difference in composition between bituminous, caking and anthracite coal? (1900.)

6. What is anthracite, and what are its properties? How does it occur, and where are the principal workings for this mineral in the United Kingdom? (1902.)

7. What is cannel coal, and for what purposes is it chiefly used?

8. Describe carefully the difference between caking and non-caking coals.

9. Name the three chief varieties of bituminous coals.

10. When coal is burnt out of contact with the air, what gases, etc., are formed, and what is the name applied to the residue?

CHAPTER IV.

BORING.

AFTER careful prospecting, and before commencing to sink a shaft, it is necessary to prove definitely the exact depth and the thickness and inclination of the coal seams, and the nature of interlying strata. These facts are established by boring a hole of a few inches diameter from the surface through the strata down to the coal seams. This boring may be accomplished either by hand or machinery. The former method is suitable only for shallow holes, and is now seldom resorted to even for these holes in this country when searching for coal, as there are so many excellent methods of boring by machinery, which do the work in a more expeditious and satisfactory way. But in some districts and for very shallow holes, hand boring is still employed. Each method will now be described in detail.

Hand Boring.—For hand boring the following apparatus and tools are needed :

(*a*) *Headgear*, to which a pulley is fixed to carry a rope used in lowering and lifting the rods.

(*b*) *Crab* or *windlass*, round the drum of which the rope is coiled ; *brace* or *crosshead* and *spring pole.*

(*c*) *Rods* connecting rope and cutting tools.

(*d*) *Cutting tools* and apparatus for *clearing the hole.*

(*e*) *Special tools* to prevent accidents, or to be used in case of accidents.

(*f*) Tools or apparatus for securing the hole in loose ground.

The **Headgear** is formed of three plain pieces of timber, frequently Norway fir, six, eight or nine inches diameter, according to the expected depth of the hole ; the height being from 25 to 35 ft. These pieces are fixed in a framing at the

bottom, and connected at the top by a bolt passing through them. This bolt also passes through a link carrying the pulley.

The **Windlass** may either be a simple barrel laid upon a frame and carried by steps, into which each end of the axle is fitted; or, it may be a stronger or more powerful windlass, geared so as to raise greater weights if the hole be deeper. The windlass may either be fitted to the headgear or be set at a short distance from the borehole. It may also be arranged to work either by hand or steam.

The **Rods** may be either of wood or iron [Fig. 19 (1) and (12)]. Generally they are of best Swedish iron of a tough quality. Here let it be specially noted that everything that goes down the borehole should be of the best, since accidents in the hole are so difficult to remedy or set right again. A borehole has been known to be lost, when over a hundred yards deep, through apparatus being broken in the hole. Not only should the material be of the best and most suitable kind, but thoroughly trustworthy, and qualified men should be engaged to make and sharpen the tools. Even the best iron or steel can be made quite unfit for use in a short time by the employment of an unskilled man to sharpen the cutting ends.

The rods for shallow holes are generally bars of iron one inch square, made in lengths of 20 to 25 feet. At each end of the rod is a screw joint, made to receive the end of the next rod [Fig. 19 (1)]. A few short lengths are kept, so that the borers can lengthen the rods gradually by the addition of one or two feet at a time.

Cutting tools consist for the most part of steel chisels. They are made of various sizes according to the hole required, and of various shapes according to the character of the strata to be cut through. They are made mostly with a plain edge, either quite straight at the face, when it is termed a **flat chisel** or **straight bit** [Fig. 19 (4)], or slightly curved, when it is called the **diamond point** or **V** chisel [Fig. 19 (6)]. The latter is suitable for hard rock, the former for all but very soft and very hard material. These chisels are made with a screw end, precisely similar to a rod, into which they screw. Their length varies slightly, but the average is about 18 to 20 inches. As the chisel is constantly wearing away, the greatest possible care is required, so that each time one comes up it will get accurately

measured, and beaten out if required to its full width. Should this precaution be neglected a few times only in succession, the hole might from that point be lessened in diameter.

For passing through gravel, a cutter known as the **T chisel** is used [Fig. 19 (5)]. For boring through sand or clay, the **auger** is used (3), a tool somewhat resembling the auger for wood.

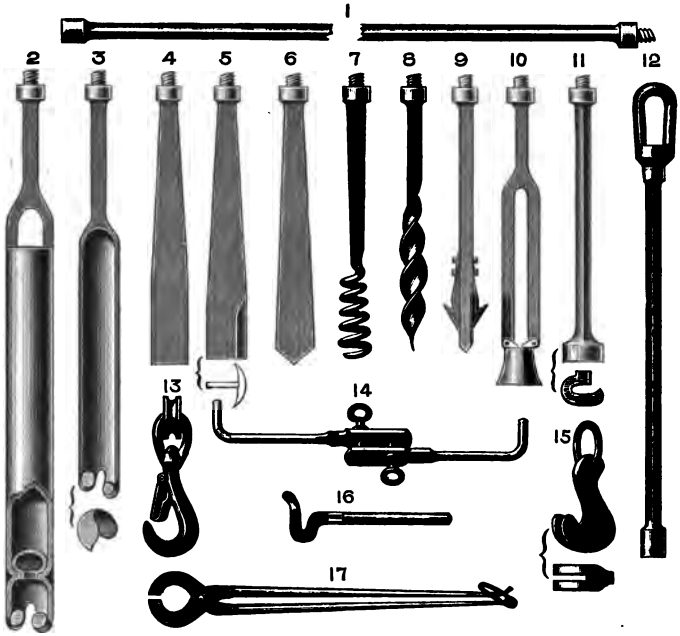


FIG. 19.—Tools used in Boring.

Clearing Tools.—When the chisels have been used for some time in chipping pieces from the rock, the hole requires cleaning out. This is done by one or two classes of tools; those acting by *rotary motion*, requiring the rods to turn them; and those acting by *jerking* and suspended from a rope. In the case of the first class the **auger nose shell** or **wimble** is the most common form. It resembles to a great extent the auger (3), but has a valve or pump inside the shell.

Another tool used for clearing is the **flat nose shell**, differing

from the last-named or auger nose only in this, that at its lower end it is not open, but flat. Like the other shell it has a valve inside to hold the material.

Another tool is the **wad hook** [Fig. 19 (7)], used for picking up pieces of broken chisels, stones or pebbles. It consists of one or two spiral springs or blades.

These are all operated by rotary motion, and consequently require attaching to the rods, which involves a considerable loss of time.

The tools of the second class are operated by being jerked or plucked up by the rope and dropped suddenly. The chief one is the **pump** (2). This consists of a cylindrical shell, with a ball or clack valve near the bottom. Of course, in using this **Ball** or **clack valve sludger**, as it is termed, it is necessary that there should be water in the hole. The sludger is dropped suddenly into the water and debris, which consequently gets above the valve. A sudden jerk upward lifts the debris, and whilst the latter is still moving upwards, the sludger is dropped down again through another layer of the debris, another sudden jerk sends this up the cylinder, and after one or two further plucks, the cylinder will probably be full and may be raised to the top. This is the most expeditious way of clearing the hole when it can be adopted, the time of lowering and raising the pump occupying, with the filling, only a very few minutes.

Casings.—When a borehole has to pass through loose sand or gravel it is desirable to have it lined. This lining is done by pushing or driving down wrought-iron pipes, put together similarly to the rods, the joints being "flush" inside and out, so that there can be no sticking of the chisels inside, or of the sides of the hole outside. The pipes or tubes are forced down by various methods. For short depths a heavy weight is sometimes dropped on them. For greater depths, they are forced down by being turned round under pressure, the bottom of the tubes always having a cutting edge. In some cases they are forced down by powerful presses.

Miscellaneous Tools.—Besides the tools and apparatus described there are numerous other things to be provided (Fig. 19), as *screwkeys*, *lifting dogs* (15), *nipping forks* (16), tools for lifting broken rods, as the *crow's foot* (11), *bell* (10), tools for lifting linings (9), and tools for regulating the size of the hole (8), *crosshead* (14), *rod with swivel* (12), *tongs* (17).

Procuring Cores.—In all percussive boring, the rocks are so broken up that much valuable information is lost. The exact structure of the rock, its colour, the rate and direction of its dip, its fossils, if any, are all lost through being chopped up. To remedy this, tools have been designed to bring up a solid core. The hole is cleared of debris, a chisel with an eccentric cutting edge is lowered, care being taken by suitable marks on the rods and a fixed plumb line, that the chisel does not get in the slightest degree turned. When this chisel has reached the bottom, a few slight blows are given without turning the rods, and it is raised again. A special tool with chisels fixed in a ring is then lowered, and a groove is cut round a circular core nearly to the depth of a chisel. When this has been raised, another one is lowered, which, by means of a spring or wedge driven down one side, breaks the core off. This core is then brought to the surface, where its composition, texture, colour, direction and rate of dip can be carefully examined.

Boring.—The necessary apparatus having been provided, and arrangements having been made for all to be kept in good order, it is customary, and generally desirable, to sink a small shaft to the depth of five or six yards. The use of this will be at once seen, when it is remembered that in letting down a chisel, and in lifting it up, only so much can be lifted at once as will extend from the top of the borehole to the pulley in the headgear, where the rope holds the top of the rods. A joint has to be broken immediately above the borehole—the rods being held by the nipping fork (Fig. 19) whilst this is being done.

The pit being sunk, the borehole is commenced, of a diameter judged by the depth of the hole, and when the hole is six or eight feet deep a "guiding tube" is inserted and securely fixed, the greatest possible care being taken to ensure its being perpendicular; for upon this depends to a great extent the direction of the hole all the way down. After fixing the guiding tube, a wooden stage is formed near the pit bottom, upon which the men stand whilst turning the rods. A crosshead of iron [Fig. 19 (14)] or of wood is attached to a short length of rods by means of the screw joint, whilst in the bottom end the chisel is fixed. One man or a couple of men now take hold of the crosshead, and lifting it a few inches drop it smartly down and thus cut or chip a small piece of the rock or other

material. Not more than one or two strokes are given before each man takes a short step to his left; thus, the borers are constantly moving round, and prevent the chisel from cutting a deep groove and thereby getting stuck fast. The head borer

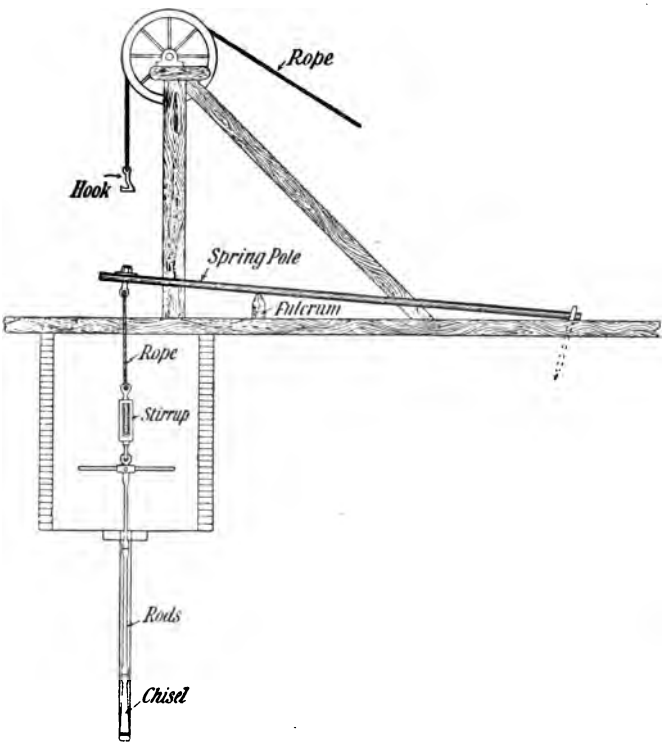


FIG. 20.—Hand Boring with Spring Pole.

will know by experience, and his assistants will soon learn by the sound and feel of the rods, when to cease cutting and let down the sludger or shell. After the hole has been cleared out a few times, the crosshead will get too low for the borers to work effectually, and either a short length of rod must be added [Fig. 19 (1)], or a rod taken off and one slightly longer put in its

place. The borers can do the best work with the crosshead at a given height from their feet, or within a short distance of that either way. For a short distance down, the borers will lift the rods themselves, but by and by, as the depth increases and the weight of rods increases, the crab or capstan will come into use, and the rods will be pulled up by the rope attached to the crosshead and passed over the pulley in the headgear. Shortly, too, additional help will be sought in the shape of assistance for working the rods.

Before steam, or machinery worked by other than hand power, is applied, assistance may be given to the borers by what is known as the **spring pole**. It consists of a long fir pole with its thick end firmly fastened to the ground, and a rest fixed nearer to the pit, the other end of the pole being over the hole. Round this end of the pole an iron ring passes with a hook underneath (Fig. 20). From this hook is suspended a rope, which is attached to the crosshead, a swivel joint being introduced to allow of the crosshead turning round freely. Between the pole and the swivel is fixed a **stirrup** (Fig. 20), which consists of a screw, working slowly through a collar as the rods go lower. When the screw has run to the bottom of the stirrup, it is unhooked, screwed up again, and a short rod added to the top of the others. The work of the borers now consists of smartly pressing down the crosshead, to strike the requisite blows, whilst the spring or elasticity in the pole lifts the crosshead to the required height. This is at once one of the most convenient, effective and economical plans for saving manual labour before applying steam or motive power, and a fairly deep hole may be bored by these means. If water is not available, or if there are other difficulties in the way rendering the use of steam, compressed air or electricity not very convenient or desirable, a depth of 300 or 400 feet may be reached. Beyond this depth, even with the best appliances, hand boring becomes very expensive, owing to the many joints that have to be screwed and unscrewed.

Machine Boring.—When the borehole is expected to go to a considerable depth, it is better to decide at the commencement to employ machinery. Of course, this plan necessitates the use of steam, and consequently requires a supply of coal and water. Hence the means of securing a constant supply of these must be taken into account, along with other considerations, when

choosing a site for boring. The site being determined, the next consideration is the selection of the system or method of boring.

We may divide the systems into two classes: in the first instance, those working by **percussive** action, or a series of blows; and those cutting by **rotary** motion.

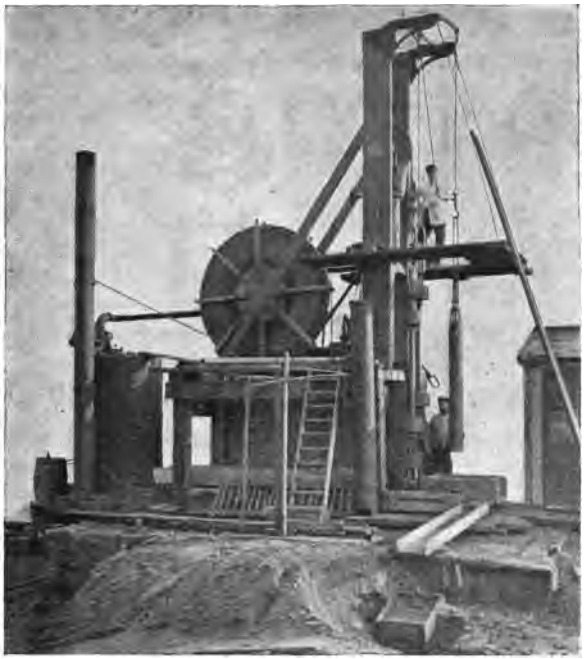


FIG. 21.—Mather and Platt's Boring System.

Mather and Platt's System.—Of the percussive class we may take the Mather and Platt's method as the chief type, as indeed it was the first great improvement upon hand boring and the use of rigid rods, which, as already explained, require much time to be spent in screwing and unscrewing the rods.

In Mather and Platt's method (Figs. 21 and 22) the rods are done away with, and a flat rope similar to a winding rope is substituted. By this means the chisels or clearing tools can be

lowered two or three hundred feet in a fraction of a minute, and brought up in about the same time. The arrangement is comparatively simple considering the work it has to do. The rope is wound upon a drum in the same way as a winding rope, the drum being turned by an engine. Between the drum and the pulley in the headgear is a frame with a clamp, by means of which the rope, when it has taken the chisels to the bottom, can be held to the frame, and so the part between the frame and the drum may remain stationary, whilst the part between the pulley and the bottom of the hole is in motion. Exactly underneath the centre of the pulley is a separate small cylinder, in which a piston moves up and down at a fairly quick rate, raising and lowering the pulley and the rope at the same time, at each up and down stroke of the piston. As the chisels are fixed to the bottom of the rope, they necessarily rise and fall with it, and in this way the cutting is done. The chisels would, of course, fall in the same place at each stroke if some means to prevent it were not taken. But by a very ingenious device the cutters are slightly turned at each stroke.

Fig. 22 shows the part above ground when in use of the Mather and Platt's boring apparatus; (*a*) is the flat winding rope; as shown the rope has been wound up, and the short chain at the end with the shackle (*o*) is hanging out of the hole; (*f*) is a guiding pulley round which the rope runs when passing from the drum (*e*) to the overhead pulley (*g*).

The first important point to be noticed is the rapidity with which the tools are let down and brought up the hole as compared with the old method of screwing and unscrewing rods.

Here the rope, coiled round a drum, is let down by a brake, or by the small winding engine, until the cutters, or chisels, or sludge pumps, as the case may be, reach the bottom. Arrived at the bottom, the rope is clamped at the point (*i*), between the guiding and the overhead pulleys, and the small winding engine, which lowered it, is stopped until the rope has to be pulled up again.

The rope being secured, another engine is put to work. This consists of a cylinder (*h*), with a piston having at the top a cast-iron rod fitted with a fork which carries the overhead pulley. Steam is admitted into the cylinder by a

valve (*k*) at the bottom; the piston rod lifts the pulley (*g*) which carries the rope and cutters, and when the piston reaches the top of the stroke, tappets below the cylinder close the steam inlet and open the exhaust, and the weight of the boring head and rope pulls down the piston, the chisels striking a heavy blow at the bottom of the hole just at the moment

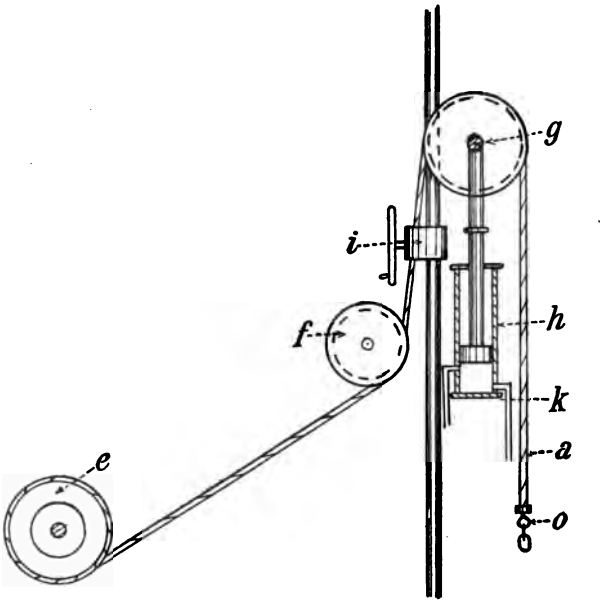


FIG. 22.—Mather and Platt's Boring System.

when the piston reaches the bottom of its stroke. In order that the cylinder bottom may be protected from damage by any unforeseen fall of the piston, the exhaust valve is placed a few inches above the bottom; so that when at work there is always a body of steam which would act as a cushion in case of need. The chisels can strike 20 to 25 times per minute.

The next point to be noticed is the ingenious device for automatically turning the boring head round with the chisels.

Fig. 23 illustrates the arrangement. It consists in the first place of a wrought-iron bar eight feet long and four inches diameter, with a cast-iron cylindrical block at the bottom. This block is fitted with holes, into which chisels are readily but firmly and securely fixed. Another block is fitted a little above to help in guiding the bar.

Fig. 23.—Cutting Tool. Mather and Platt's System.

A little higher still is another guide having plates fastened on with ribs of a saw tooth or ratchet shape, but not seen in the illustration, catching in one direction only. These plates help to turn the chisels, catching the sides of the hole as they rise and fall. As each alternate plate has the projecting ribs inclined in the opposite direction, one half of the ribs assist to turn the chisels on rising and the other half on falling.

But above this guide is the arrangement by which the definite rotation is chiefly secured. Two collars are fastened to the bar about 12 inches apart, and shown in Fig. 23 above the broken bar. The upper face of the lower collar and the under face of the upper collar are formed similarly, each having deep ratchet teeth of about two inches pitch set exactly in line with each other.

Between these collars is a deep bush which slides freely on the boring bar, and is formed with corresponding ratchet teeth on both its upper and lower faces; but those on the upper face are set half a tooth in advance of those on the lower, so that the perpendicular side of each tooth on the upper face is directly above the centre of the inclined side of a tooth on the lower face. To this bush is attached the bow by which the whole boring bar with the chain and shackle is suspended from the end of the flat rope. The rotary motion is obtained as follows:

When the boring tool falls and strikes the blow, the lifting bush, which during the lift has been engaged with the ratchet teeth of the top collar, falls upon those of the bottom collar, and thereby receives a twist backwards through the space of half a tooth, and on commencing to lift again, the bush rising up against the ratchet teeth of the top collar receives a further twist backwards of half a tooth. The flat rope

is thus twisted backwards to the extent of a whole tooth, and, as soon as the tool is lifted, the rope begins to get back to its place, untwisting itself, and thereby rotating the tool to the extent of a tooth between each two blows, so that by an entirely automatic motion the chisels fall each time in a different place.

To obtain solid cores by this machine, all the inside cutters are removed, and only the outer circle and the few cross chisels alternating with them left in. By working with these, a conical core may be formed, longer or shorter according to the inclination of the chisels. Gradually this core gets jammed between the cutters, and is broken off and brought up by the boring head.

The Diamond Borer.—The principle of this borer (Fig. 24) differs from Mather and Platt's, in that it cuts by rotary instead of by percussive motion. To do this, of course, requires a tool harder than the rock to be pierced, and this is found in the diamond drill. The diamond used in the drill is not, however, that used as a gem, but an inferior kind known as "bort" or "carbonate," a crystallised form of the black diamond. A number of diamonds are set round the edge of an iron or steel cylinder called the *crown*, and to this crown the rods are attached. The diamonds are embedded in the iron or steel crown, and the iron is then hammered over them, leaving only the amount of projection necessary to allow the debris and water to pass underneath the crown. Care must be exercised in the setting, so that it will be all but impossible for a diamond to get out of its place in the hole. The crown in which the diamonds are set is screwed on to the bottom of a set of tubes or hollow rods, which not only give the rotary motion to the borer, but serve as pipes down which water under pressure is supplied to the diamonds to keep them cool, and

FIG. 24.—Diamond Borer.

to carry away the debris up grooves cut in the crown, which then settles in the space (*d*) (Fig. 24).

The boring rods are actuated by a small engine on the surface, attached to the rods by suitable gearing. The speed of the borer is about 250 revolutions per minute. The drill cuts through the hardest rock. The ordinary rate of boring is stated to be one inch per minute in quartz; two to three inches per minute in granite and the hardest limestones. For clay, sand and other soft strata this borer is not suitable.

The Davis Calyx Drill.—This drill (Fig. 25), which has been extensively used for prospecting in Australia, was brought over to this country a short time ago, and many holes were bored by it in the search for coal in Kent. In the manner in which it is driven it is like the Diamond Borer, and water is also sent down the rods to the bit in the same way as that adopted in the latter.

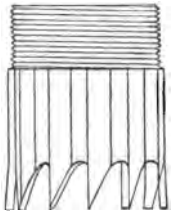


FIG. 25.—Cutting Tool of Davis Calyx Drill.

The cutting tool, however, consists of the end of a circular pipe or shell, in which are cut several sharp points or teeth as in Fig. 25. These are formed and kept sharp in the same way as the points of a saw, and it is only necessary to cut the teeth deeper in the pipe as they become worn and dull in order to sharpen it. The renewing of the tools is therefore a simple and inexpensive operation as compared with the renewing of the stones of the Diamond crown. In order to keep the hole sufficiently large to allow the apparatus room to descend, and in order also to cut the edge of the core so as to allow of the free and easy rotation of the head, the teeth are slightly projected outwards and inwards. When the rods are twisted, the teeth bite securely into the rock and remain stationary for a moment. As the pressure is sustained until the resistance of the strata is overcome, the cutters shoot forward, breaking off small pieces of rock, and become embedded again, until once more urged forward by the twist of the rods.

It is thus seen that the cutting of the hole is due more to a percussive than a rotary action. The debris is carried up the outside of the cutting head by means of the stream of water, which increases in speed owing to the reduced space until it

arrives at the top and open end of the calyx (Fig. 25), where the heavier debris settles down into it, to be raised subsequently to the surface. The operation of taking out the core is very simple. A few hard pebbles are dropped down the pipe and immediately find their way to the space between the core and the sides of the cutter. Here they become wedged tightly when the rods and cutter are lifted as in the Diamond method, until, after sufficient power has been exerted, the core breaks off and is lifted up. Although a comparatively new system of boring, the Davis Calyx method has already proved to be a quick and effective means of boring either large or small holes where cores of the strata passed through are required.

Crooked Bore Holes can be surveyed by a method devised by Mr. M'George. A clean glass tube containing hot gelatine, together with a magnetic needle and a delicate plumb bob, are lowered into the hole. Either one or more of such tubes can be used. They are kept in the hole until the gelatine has had sufficient time to cool and set, and are then withdrawn. The angle formed by the needle and plumb bob, unless they coincide, denotes the amount of deviation from the vertical.

Accidents.—The accidents in boring may be comparatively few or many, according to the provision made at the beginning. If good workmen and the best materials are not employed, the latter state of things may be looked for. The chief accidents are due to rods breaking or falling down the hole ; sides of hole falling in and jamming the rods. If a rod breaks in the hole, a tool called a *crow's foot* [Fig. 19 (11)] may be used, or, if the fracture be a little above a joint, a *bell*, with or without a screw, cut inside [Fig. 19 (10)]. For picking up small pieces of chisel or iron or steel, the *wadhook* [Fig. 19 (7)] is used. If all attempts to draw fail, then there is nothing left but to cut the obstruction into small bits. When linings are to be drawn out of the hole, and the sides press too heavily upon them, a *Kind plug* may be used. This is a wooden ball, which is dropped down the hole and a little sand or gravel dropped in, causing it to grip the side ; or a special tool may be used which will cut the tube in short lengths, and these may then be easily drawn.

Questions on Chapter IV.

1. What tools are needed for boring a hole by hand in soft strata?

2. Describe and sketch the following tools or appliances used in hand boring: "rods," "cutters for hard strata," "clearing tools," "wadhook," "sludger," "crow's foot," "spring pole," "stirrup."

3. How may cores be procured in hand boring?

4. Describe the Davis Calyx method of boring.

5. Describe the Diamond system of boring.

6. What are the advantages to be derived by obtaining cores during boring?

7. How are deep holes bored for exploration purposes? Describe the method of carrying out such a work, noticing the different accidents liable to occur during its progress. (1898.)

8. How would you endeavour to extract a set of boring rods after a breakage of one of the rods 300 feet below the surface? (1901.)

9. Describe and sketch the cutting tool used in Mather and Platt's system of boring.

10. What are the advantages of using ropes for raising and lowering boring rods and tools?

CHAPTER V.

SINKING.

Sinking consists chiefly in boring holes for blasting, in filling, in sending up and banking the debris, and in supporting and walling the sides. These operations make sufficient labour in ordinary circumstances, but if to these has to be added the pumping or winding of a large quantity of water—which collects as a rule at the bottom of the shaft, where it greatly impedes the proper sinking operations—it will readily be seen that sinking shafts may be a very serious undertaking.

It may be said that the methods adopted during sinking are those which have been employed for many years, and that improvements in apparatus for sinking have not been introduced as often as those for getting or delivering the coal. There can be no doubt that few sinkers are prepared to substitute compressed air, or electric rock drills, for the old fashioned **jumper** or the **double-handed set of drills**. It is true that safer methods are now adopted in the processes of winding and banking. The reason for this lack of enterprise is not difficult to understand. The sinking of pits is not a part of a mining engineer's regular duty. It is only an occasional undertaking, and as a rule the contract for the sinking is left to a man, or set of men, who have grown accustomed to certain methods. If left to these methods, it is probable that the work of these men will be better and more quickly done than if the manager attempts to introduce new methods and apparatus to which they have not previously been accustomed. Serious consequences, however, often arise through a manager having to rely too much upon the experience and skill of the master-sinker or contractor. Accidents or breakdowns in shafts are invariably serious, either in life or money.

It is therefore necessary that, while the sinking is proceeding, the manager should be constantly engaged in superintending the operations.

Preliminary Excavation.—After fixing the centre of the proposed shaft and marking from this the circumference, the actual excavation begins. To begin with there will be little difficulty in getting out the ground; more trouble will be experienced in keeping back the soft sides of the shaft. This will best be done by the employment of wooden curbs or rings and boards which will be described later. The soil and clay first met with are got out by spades and thrown by the sinkers on to the surface until a depth of about 6 feet is reached. Supports for the sides are then put in and a small platform erected, on to which the sinkers can throw the debris, another set throwing it from the platform to the surface, where it is piled up so as to raise the level of the surrounding land. After a depth of 12 feet or so has been reached, it will be necessary to use a **hoppet** or **kibble** to raise the debris, a small headgear and engine with rope being used for the purpose.

Mode of Getting Out the Ground.—When the solid rock underlying the subsoil is reached, holes are drilled by one of the following methods:

1. Jumper Drills.
2. Double-handed Set of Drills.
3. Hand Machine Drills.
4. Power Machine Drills.

There are few better methods of putting in a deep vertical shothole by hand than by means of a **jumper**. Using one of these drills, which vary in length from 4 to 12 feet, the sinker has merely to stand with the drill in his hands, and lift it up and then release it repeatedly, the weight of the drill itself being sufficient to cause a good sharp blow.

Where the rock is too hard for this, a shorter drill held by one man, and struck in turn by two others with heavy hammers, is used, this being an old method which is so efficient that few sinkers are prepared to give it up in favour of rock drills.

In drilling the holes for the **breaking in** or **sumping shots**, a **two-handled ratchet drill** is now commonly employed. This drill may also be used for putting in the holes in the shaft sides in

order to introduce the plugs of bricking rings. It is an extremely useful arrangement, since two men can readily put in a large number of holes in any position. Pegs are fixed in the side of the shaft against which the drill is set, or bearers are placed across the shaft for the holes near the centre.

Up to the present time the majority of shafts have been sunk by the tools described, and even yet, in certain circumstances,

FIG. 26.—Sinking by means of Rock Drills.

hand boring machines are extremely serviceable; but, where rock or hard ground is expected in great thicknesses, these appliances are slow and costly. It must also be remembered that at the present time shafts are being sunk of much greater diameter than formerly, and this fact leaves greater scope for the introduction of machinery. Rock drills have many advantages when used in sinking (Fig. 26), but they have one great drawback, viz., the difficulty of removing them after each operation, and before the shots are fired, so that they may be uninjured by the blast. Recently, even this difficulty has been

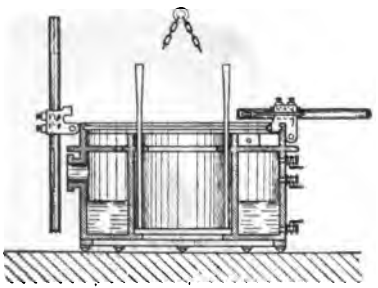
got over by the introduction of a sinking frame designed to increase the rapidity with which the drills can be set up and operated, and afterwards withdrawn to a place of safety.

Walker's Patent Sinking Frame, made by the Hardy Patent Pick Co. of Sheffield, has been tried in a few shafts, notably in the Sherwood Colliery Co.'s new sinkings at Mansfield. Here two shafts 25 feet 6 in. in diameter have been sunk with great success; the following details briefly describe the plant used:

A circular steel frame (Fig. 27), 8 feet in diameter, has an Annular Tee slot cast in its entire circumference. Fitted in this slot are suitable clamps, each carrying telescopic arms, projecting so that the diameter over such arms corresponds approximately to the diameter of the shaft to be sunk. Upon these arms are mounted an improved form of compressed air drills, preferably two on each arm. This plant is put together complete on the bank and lowered by means of winch and guide ropes to the bottom. It will, therefore, be seen that the whole of the drilling plant can be lowered at once, and raised again after the completion of the boring, thus abolishing the slow and tedious methods of clearing the pit bottom. In fact, in actual working, from the time of rapping to the lowering and starting of 8 drills in the bottom, less than ten minutes have elapsed. This advantage, however, is not the only feature in connection with the frame. Its circumference is so indexed that any number of holes may be drilled mathematically correct without the trouble of marking out and consequent loss of time, an item which has hitherto been of very serious moment. Reducing this to actual figures, it may be taken that a round of 60 holes 6 feet deep may be drilled in hard limestone (25 feet 6 inches diameter) and the gear raised to the bank in two hours and a half, a result which has probably never before been obtained.

Through hard limestone a total of 10 yards per week of 25 ft. 6 in. diameter has been attained, with an average (including all stoppages) of 7½ yds., and in the softer strata and the coal measures, where power drills are unnecessary, hand drills may be applied to the frame and the proportional speed of sinking equally well maintained.

In any of the methods used, the sumping shots, as shown in Fig. 28, are first put in and fired. The result of firing these shots is, that the shaft is left in the condition shown in Fig. 29. The outside circle of holes is then fired, care being taken not



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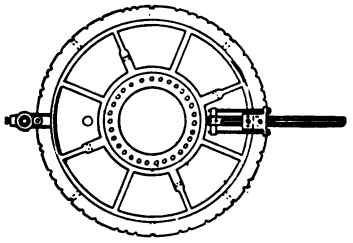

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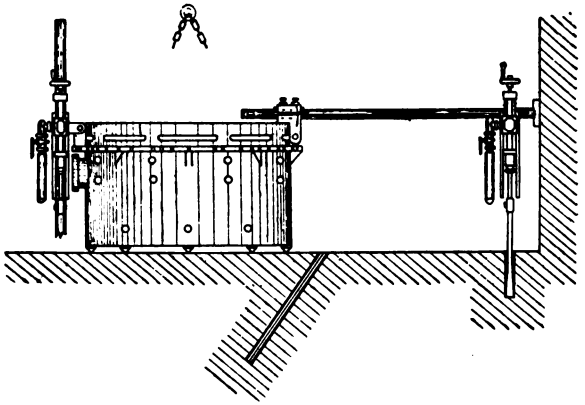


ELEVATION.

FIG. 27.—Walker's Sinking Frame.

to drill the holes into the solid walls of the shaft or beyond the bottom of the **sump hole**, shown in Fig. 29, which is the hole formed by the first round of shots.

FIG. 28.—Position and Direction of First Set of Shot Holes.

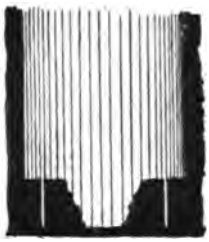


FIG. 29.—Position and Direction of Second Set of Shot Holes.

Explosives and Modes of Firing.—The kind of explosives suitable for sinking operations, with the method of using them, may vary considerably from that in ordinary underground work. Some engineers, while using electric firing and high safety explosives underground, prefer, in sinking shafts, to use fuse and powder, or other explosives. The conditions under which firing is conducted in shafts are not such as obtain underground. It is necessary in shafts to fire a round of holes at one operation. It is quite common for these to be fired under water, and the tamping or filling up of the hole with clay, etc., is not always possible. There is rarely any accumulation of gas, and no person is down at the time of firing. In these circumstances, an explosive is requisite that will stand water, requires little or no tamping and is sure in its action.

Explosives.—A good explosive for this class of work is **Gelignite**, and, like gunpowder, it is also very suitable for dry

ground. Other explosives used are: *Tonite, Gelatine, Bull-dog Powder*, and the *Nitrate of Ammonium Explosives.*

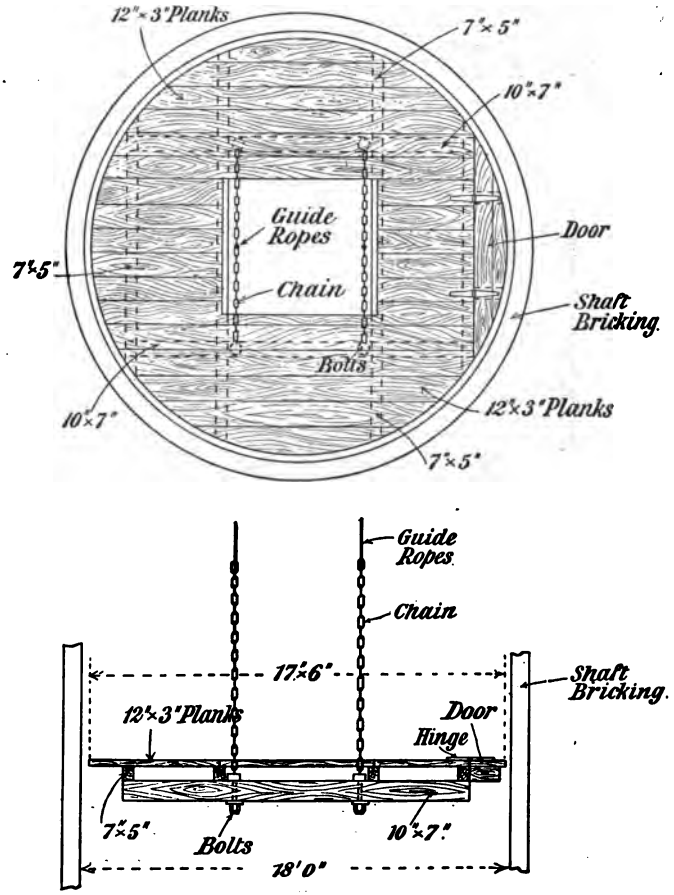


FIG. 30.—Plan and Section of Bricking Scaffold.

Safety Fuse.—The ignition of the shots by a *safety fuse* remains in favour. By this means the shots can be fired off in a definite order, with slight intervals of time between

each shot. A miss-shot can thus be detected. The chief disadvantage of fuse firing is in the lighting of the fuses, which must be done rapidly; the men must be raised out of danger carefully, but without loss of time.

Electric Firing.—In firing by this method all wires are coupled together in series, and the shots fired simultaneously.

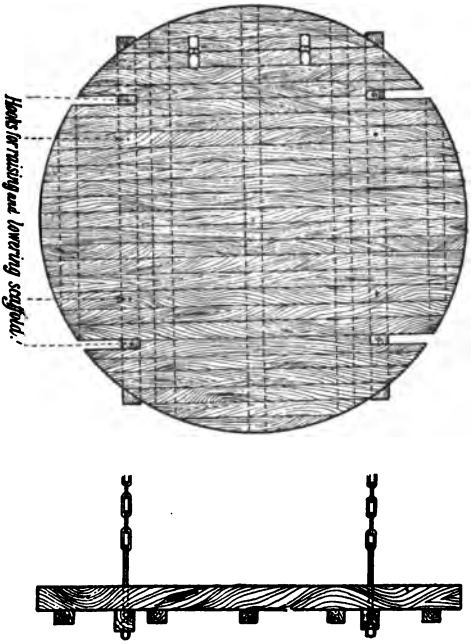


FIG. 31.—Plan and Section of Bricking Scaffold.

In one respect this is a safer method of firing, as the battery is only connected after the sinkers are out of the shaft.

The disadvantages of electric firing in shafts consist in

(1) The fact that in simultaneous firing it is impossible to detect the occurrence of a miss-shot, and

(2) The shock in the shaft in hard ground being very severe.

Fuse and Electric Firing combined.—A combination of the two forms of firing has been tried. In this case the ends of the

fuses are joined together into one central coupling called a "Bickford's Igniter," and these ends are ignited by means of the battery.

Winding and Banking.—**Kibbles** or **hoppets** are now chiefly used in winding and banking. The material is tipped easily and rapidly from them into tipping waggons. This plan is a great improvement on the old method, where hoppets were used which were suspended by chains requiring to be unhooked after lowering on to the banking trolley before being attached to a second hoppet. Where the catch which holds the arms is not fastened automatically, care should be taken to see that the pin for securing them is in position before commencing to raise or lower the hoppet.

By means of the **Galloway scaffold, guides, rider and doors,** the operation of raising and banking the debris has now become both safe and rapid, and to Prof. W. Galloway must be given the chief credit for a decided improvement in the methods of sinking.

A **Bricking Scaffold** (Figs. 30 and 31) is suspended by two wire ropes, passed over two pulleys in the headgear, and attached to two drums of a small engine. A suitable engine for this purpose is a self-contained Main and Tail Rope Hauling Engine, having both drums keyed on to the shaft. When sinking is completed this engine can then be used for

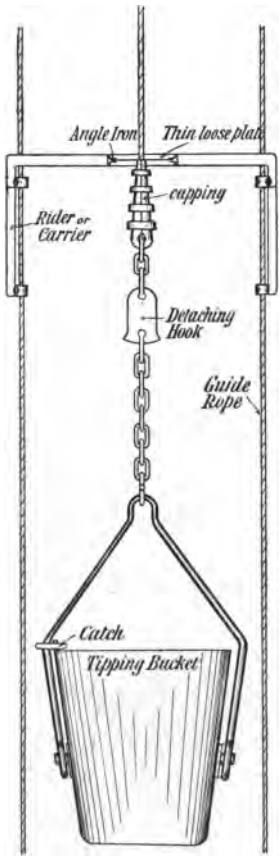


FIG. 32.—Winding-in Sinking Shaft by means of Hoppet, Guides, and Rider.

its proper purpose. The scaffold is raised and lowered by this engine as required for bricking the shaft.

The **Galloway Bricking Scaffold** consists of two wooden platforms, connected together by four upright angle irons. The distance from the higher to the lower stage is about 10 feet. Each stage is formed of a framework of iron, covered by timber,

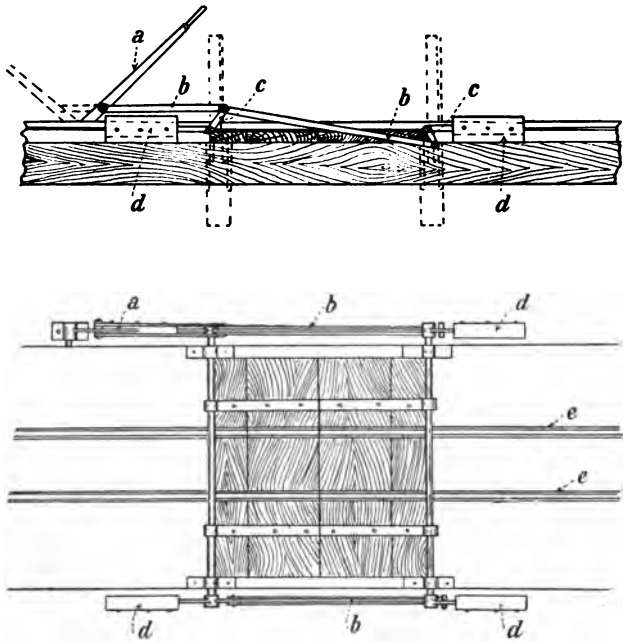


FIG. 33.—Plan and Section of Galloway Folding Doors.

having a hinged door upon one side, and an opening in the centre through which the hoppet passes in raising and lowering. It is only necessary to use two platforms in this way in cases where the bricking is being done while the sinkers are at work. In any other circumstances, one platform will be sufficient. The wire ropes by which the scaffold is suspended serve also as **Guides** for the hoppet. A **Rider** (Fig. 32), consisting of a frame of iron, clasps the guides on each side, and through a hole in the

centre of the scaffold the winding rope passes. The winding rope has a buffer of sheets of iron and india-rubber formed near the capping. This buffer, being too large to pass through the hole in the rider, lifts and carries the latter up and down the shaft when raised or lowered. The hoppet is thus steadied and guided, and may be raised with safety at a greater speed than was formerly possible. When lowering the empty hoppet, the rider, on reaching the upper platform, is left at the point where the guides are attached to the scaffold, the hoppet passes through the opening, and in this way is lowered to where the actual sinking is being done.

The **Galloway Folding Doors** are used for banking, and serve also as a protection or covering for the pit top. Two hinged and balanced doors (see section and plan in Fig. 33) are placed over the pit top. The doors are opened by a handle or lever (*a*), which is pushed or pulled over like the lever used for working the catches under the cages at the top of a winding pit. This handle, being connected to the hinges on each door by the arms (*b*), and eccentric pieces (*c*), causes each door to lift at the same time. Weights (*d*) are fitted so as to balance the weight of the doors, and thus decrease the effort required to lift them. The pit, being already fenced on each side, is now protected on all four sides. Rails (*e*) are placed over the doors, upon which a tipping waggon may run. When the hoppet arrives above the doors the handle is operated, the doors closed down, the tipping waggon (Fig. 34) run beneath the hoppet, and thus the contents are easily overturned into the waggon, which is run off to be tipped. The doors are again opened to allow of the descent of the hoppet, and are allowed to remain open during the time the hoppet is in the shaft.

FIG. 34.—Tipping Waggon used at Surface during Sinking.

A **Banking Waggon** consists of a platform on wheels, which is run over the pit top when the hoppet is raised. The contents of the hoppet are then overturned into the tipping waggon, which is run on to this platform, or it may be lowered on to a small trolley running on wheels, disconnected from the rope,

and another hoppet hooked on and lowered into the shaft, while the first hoppet is run along the dirt heap to be tipped. This arrangement is slow and the labour considerable, although it has been the method generally adopted until comparatively recent times.

Lining the Shaft.—Material and Mode of Putting In.—Having sunk the shaft a sufficient distance, it becomes necessary to

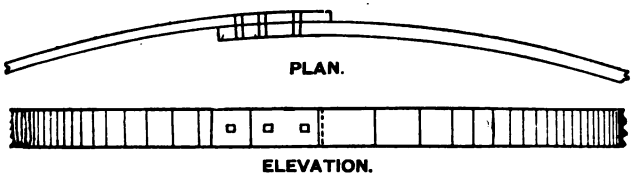


FIG. 35.—Segments of Iron Curb or Crib.

secure the sides. In order to do this temporarily, flat iron rings, say 3 in. by 1 in., are suspended from the surface and are placed at intervals of about 5 ft. from one another. These rings (Fig. 35) are made in segments, bolted together to make one complete ring. Behind these rings, placed closely together, are boards or battens about 1 in. thick, and wood wedges are driven in between the rings and the boards. For passing through loose surface strata, elm wood rings about 6 in. by 6 in., in segments not exceeding 6 ft. in length, are used, being stronger than the flat-iron rings. The segments are fastened together as in Fig. 35, the surmounting timber bearing the name of "Clope." Battens are likewise driven behind these rings, the diameter of which must be sufficient to allow of the permanent lining being built up inside them, thus requiring at least the thickness of the lining, say 9 in. or 14 in., to be allowed. Each elm ring is suspended from the one above by hangers of say 1 in. square iron, bent over the upper ring and under the lower. At least one hanger should be used to each segment. If there is a quantity

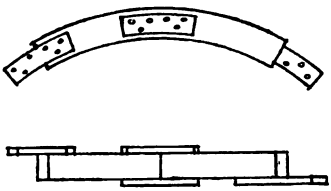


FIG. 36.—Wood Rings.

of water accumulated, and it is necessary permanently to keep it back, special processes will be required, but in ordinary

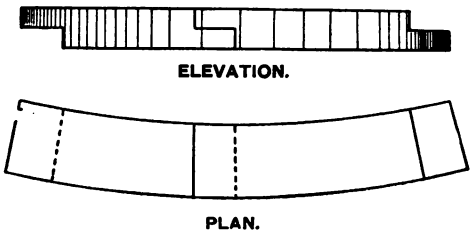


FIG. 37.—Segments of Wooden Curb or Crib.

sinking, having reached the solid bed of strata, preparation is made for the permanent lining of the shaft.

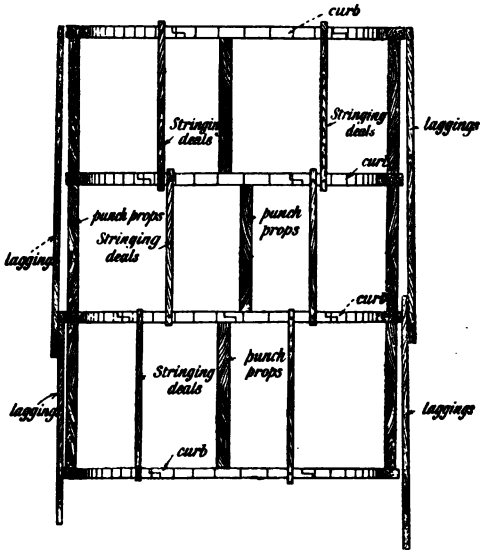


FIG. 38.—Arrangement of Timbers for Temporary Support of Shaft Sides.

Preparing the Bed and Ring.—The bottom of the shaft, for some distance away from the sides, is carefully chipped, so that

a level surface is made in an annular form all round the shaft. This bed must be slightly wider than the ring which is to be placed on it. The bricking ring segments are then sent down the pit, having been previously fitted together and marked on the surface. These segments are laid on the bed and tightly bolted together with thin wooden liners between them. It is necessary to describe the ring more fully.

Bricking Ring.—The bricking ring consists of a number of cast-iron segments (Fig. 39) of a certain shape, which, when joined together end to end, make a complete circle. The width of the ring, or its distance from front to back, should be equal to the thickness of the proposed lining of the shaft. The inside or least diameter of the ring, when it is bolted tightly together,

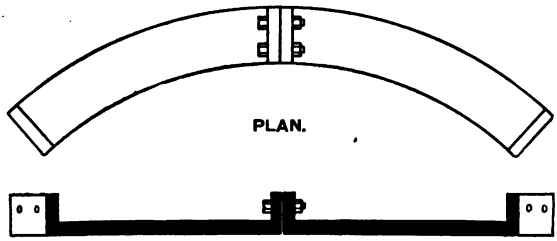


FIG. 39.—Bricking Ring.

should be equal to the finished diameter of the shaft after the lining is completed. An upright projection is cast on the front of the ring, which gives strength to it and also forms a very convenient template or guide by which to set the first course of bricks. The segments are in lengths convenient for handling, not exceeding 6 ft., and at each end of the segment upright projections or brackets are left. Holes are left in these end projections to allow for bolting the segments together.

As the strata near the surface are generally softer and more liable to crush inwards than the more solid rock lower down, it is usual to put in a thicker lining for the first length.

The most common lining for pit shafts is brickwork; but stonework, where stone is plentiful, would do equally well. In any moderately large shaft it would not be wise to put anything less than 14 in. of lining for the first length, and

where the surface is liable to be often under water, 18 in. of brickwork, 6 in. of clay and 12 in. of concrete may be desirable. Where the temporary rings and battens have already been put in, the shaft ought, if possible, to be sunk sufficiently large to allow of this lining being brought up through the rings that are already in. This does not mean that the battens and curbs are to be left in, but it allows a little margin in case the ground gives way a little as they are being loosened and taken out.

Laying the Ring.—Having prepared the bed, the ring is laid on it and then levelled and carefully centred. The latter operation is necessary for the purpose of keeping the shaft truly perpendicular. A centre line is slung from a definite mark at the pit top; this mark is retained by boring a hole through a stout piece of wood and stretching it across the shaft. By making it a true fit between or over the beams that carry the doors over the shaft, this stretcher can be removed or inserted as required. The centre line should consist of bare copper, or of galvanised iron cord similar to that used for clock weights. A weight is hung on this cord and allowed to steady itself. The ring is set carefully so as to be an equal distance all round from the centre line, and is then held in position by wood wedges.

Bricking Lines.—Arrangements must be made for hanging bricking lines from the surface, to correspond with the inside lining of the shaft. These lines are struck off on the surface, and should not be more than 2 ft. apart. After the bricking ring has been tested by these lines also, the lines may be fastened to the ring. The lining is then built to them all the way to the surface. Small wood templates, 2 ft. long, and cut to arcs of the pit, should be used for the purpose of keeping the true circle of the pit.

The Lining.—The brickwork (or stone) is set in good, well-ground mortar, and in no case should it be of less thickness than as given above, and 9 in. for all the deeper lengths. Where the shaft is too large after the specified thickness has been put in, the space between the lining and the strata should be filled in with some hard substance such as concrete, or *bricked* solid throughout. By adopting either method, any slight giving way of the ring carrying the brickwork is not serious, as the hollow places formed in the shaft act as ledges

upon which the brick lining rests. The ring is thus relieved from the dead weight of the superincumbent brickwork.

The **number of bricks** required to line a shaft is calculated as follows:

$$\frac{(D^2 - d^2) \times 0{\cdot}7854 \times 3 \times 330}{27} = \text{number of bricks for 1 yard in depth,}$$

where D = outside diameter of brickwork,
d = inside „ „
330 = number of bricks, with mortar, in 1 cubic yard.

(There are 384 bricks, without mortar, in one cubic yard of work, but with mortar it is usual to allow 330 to the cubic yard, or 1,000 bricks in three cubic yards.)

In one superficial yard of brickwork there are, in 9 in. work, 80 bricks.

In one superficial yard of brickwork there are, in 4½ in. work, 40 bricks.

Laying the Second and Subsequent Rings.—A slight variation is made in the laying of rings in the more solid ground from that usually employed in laying the first.

Instead of a prepared bed, plug holes are drilled into the sides of the shaft, and iron plugs, averaging about 3½ ft. long by 2 in. diameter, are driven into the holes. These plugs are fixed as level with each other as possible; the ring is laid on the top of them and centred as before. At least two plugs should be used to each segment of the ring. It must be observed that the plugs will vary both as to length and strength, according to the nature of the ground in the first instance, the softer ground requiring longer plugs; and in the second instance, according to the space left in sinking beyond the outer diameter of the ring. This amount of space is important, as a much longer and stronger plug is required where the space is greater than usual.

Sinking through Soft Ground.—There are several methods of sinking through soft ground, the chief of which are:

1. Pile Driving; also called "Spilling" or "Forepoling."
2. Wooden or Iron Drums.

Pile Driving.—In Pile Driving a wooden curb is first formed in segments, the curbs being as a rule about three to six inches wide. This curb is laid in position, and piles consisting of planks about six inches broad, three inches thick, and nine,

twelve, or fifteen feet long, as may be thought best, are driven down. In stronger ground, shorter piles are used. The lower ends of the piles are tapered on the inside, and a wrought iron hoop fixed around the top. If the sand be very fine or wet, the piles are carefully cut and bevelled to the circle or radius of the pit. The sand, gravel, or other material is then got out at the bottom until a sufficient depth is reached to put in another curb; so the process is repeated until the bottom of the piles is reached within about a foot. This method of pile driving is simple and straightforward, but it has the drawback of lessening the diameter of the pit at each new length of piles, as the second length of piles is put inside the bottom curb after the lower end of the first length has been reached. We thus see that if a pit were required to be 18 feet diameter when finished, and there were 30 feet of sand and 10 feet length of piles to be secured, this would mean three sets of piles; and if curbs six inches broad, and piles three inches thick were used, the shaft would have to be started with a diameter of

$$\begin{aligned} &18' + 3(6'' + 3'') \times 2 \\ &= 18' + 3 \times 18'' \\ &= 18' + 54'' = 22'\ 6''. \end{aligned}$$

Drums used in sinking are of two kinds, wood and iron. Wood has one advantage over iron; it does not break or give way entirely, so soon as iron; in most other respects iron is preferable.

With **Wooden Drums**, a curb of 12 inches or more in breadth, according to the proposed weight or strength required, is got in position on the site of the pit, a circle of masonry is laid upon it (Fig. 40) and built up to a height of about three feet, after which a second curb is laid upon it, and connected to the first by means of iron bolts passed through the brickwork. Behind the brickwork is then placed an outer coating of timber, formed by planks nailed to the curbs, tongued and grooved into each other, and made as water-tight as possible. Another length of brickwork is then built upon the second curb, and planks laid behind these as before. When this is lowered into the shaft, and forced by means of additional weights if necessary through the soft strata, a good and strong protection against the soft unsubstantial strata is obtained, and as the space upon the last curb is being constantly built up as the drum lowers itself

through the strata, there is no danger of an inrush of debris from above. The ground in the shaft is being sent up meanwhile, and this process continues until more solid ground is reached, when of course the drum ceases to sink, and the ordinary methods of sinking may be continued. The greatest

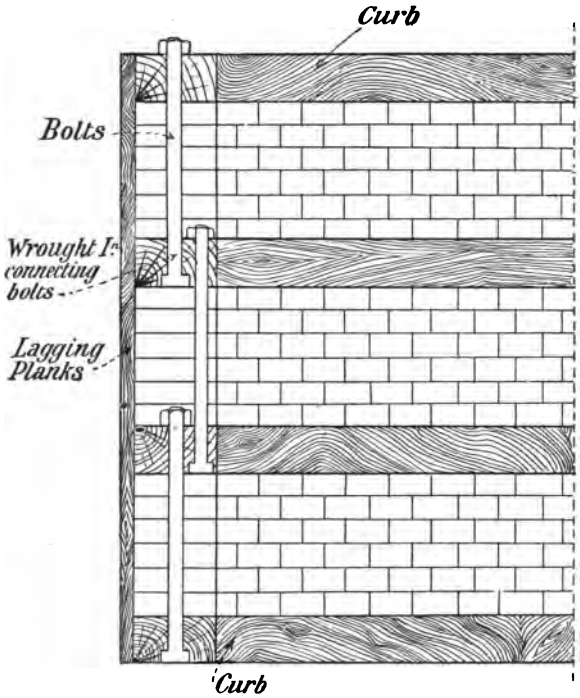


FIG. 40.—Wooden Drums with Masonry.

care is necessary in sinking by this method to keep the drum in a vertical position. Wooden drums are more difficult to break than iron, and therein lies their chief advantage.

Iron Drums are formed of curbs of $\frac{3}{4}$ in. iron in segments of four or five feet long and two feet deep. Unlike tubbing used against water, the flanges or strengthening brackets of these curbs are inside the body of the curb, in this way presenting a

smooth surface to the sides of the pit. They are fastened together by means of bolts, sheet lead being used to ensure perfect jointing, and are lowered into the shaft in the same way as wooden drums. To enable a more rapid progression through the soft strata, a number of teeth forming a kind of cutting edge are placed on the bottom segment, and in this way, provided the strata is not too hard, the drum cuts its way down, assisted where necessary by weights placed upon the ribs. The chief recommendation of iron drums is that they take up less space in the shaft, and where it is required to put in a number of drums, telescoped into one another, the saving in space is very great. Again, they can be more readily prepared and placed in position than wooden drums.

Sinking through Water-bearing Strata.—Where the methods just described are insufficient as a means of holding back quantities of water, one of the following special processes will have to be adopted:

Coffering.—In coffering, the water is shut off by means of a perfectly water-tight lining of bricks and cement. This is done as follows: After carefully preparing the usual foundation for a wedging curb or bricking ring, which should be a few feet below the strata containing the water, the curb or ring is placed securely in position, wedged, spiked and cemented. A good thickness of brickwork is then carefully put in, the joints of each course of bricks being divided horizontally and vertically, and the space behind filled up to a height of six feet above the curb with cement. The remaining space up to the next curb is then left for the water, which is guided into the curb or ring, and from thence into the shaft, or it may be stopped off by placing plugs in the holes through the rings, commencing at the bottom, and passing gradually upwards.

Tubbing consists of using cast-iron rings of tubbing in place of brickwork and cement, and is used where large feeders of water are met with, or where the large space required for brickwork is not available. The ring, or wedging curb, is first placed in position as in the case of coffering, and after laying down a bed of fir or oakum $\frac{1}{2}''$ thick upon the ring to form a secure joint, the plates of tubbing, which are in segments generally two feet high and four or five feet long, are placed upon it. The plates are smooth on the side presented to the shaft, the strengthening flanges being at the back. On one side

and the top, projecting flanges are formed, which serve to keep the segment together. After one ring of plates has been laid, it is tightly wedged in position and another layer of timber or oakum placed upon the top. A second ring is then fitted in position, and so on to the top of the water-bearing strata. Each segment is provided with a hole, which serves the double purpose of a means of lowering into the shaft, and as an outlet for the water until it has been stopped by plugs in a similar manner to that adopted in coffering. Wedging curbs are placed between the top of the tubbing and the last length of brickwork, and the joints finally made tight and secure, the vertical joints of the brickwork being broken so that wedges may be driven in to tighten.

The **Thickness of Metal Tubbing** required for various depths and diameters of shafts may be found in different ways. The formula given by M. André in his book is probably the safest to follow.

Where the segments do not exceed two feet in depth : let H equal the head or depth of water in feet, D the diameter of shaft in feet, T the thickness of the plate in inches.

Then $T = 0{\cdot}35 + 0{\cdot}00025\ HD$.

EXAMPLE.—*Determine the thickness of metal tubbing required to line a shaft of 20 feet diameter, the depth of water being 150 yards.*

$$\text{Thickness} = 0{\cdot}35 + 0{\cdot}00025 \times 450 \times 20 \text{ feet.}$$
$$T = 0{\cdot}35 + 2{\cdot}25.$$
$$T = 2{\cdot}6 \text{ inches.}$$

Method of Lining the Shaft where it is Necessary to Collect the Water.—It is often considered advisable to collect the water which accumulates in the pit in the course of sinking. Among the reasons for collecting the water are :

1. The water may be good for boiler purposes, and where surface water is scarce this is a consideration.

2. It may be wise to relieve the pressure of the water so as to take no risk of an outbreak from the roof of the mines after opening out is commenced.

3. It may not be expedient to keep the water back by tubbing.

The water may be present in many fissures or layers ; it is necessary to collect it carefully together, and to bring it to the

front of the brickwork lining, so that it can be disposed of by means of pumps or winding.

The following method may be followed for the first length of lining, a very similar process being required for the lower lengths. The bottom of the shaft is prepared in the same way as for ordinary brickwork, but it is necessary to make the bricking water-tight for a short distance up from this bed. To do this a garland of clay is laid on the inside of this bed round the shaft. The ring is packed up on temporary packings about two inches above the bed. Liquid cement, or a good mixture of sand and cement, is then run round the back of the ring, and pouring in is then continued until the whole ring is well surrounded and packed with cement. The garland of clay retains the front of the cement until it is set. At the right moment the packages are released; and the ring beds itself into the cement. The brickwork and the backing are then laid in cement, and the whole brought up solid for a short distance to the place where it is proposed to collect the water. A good level bed is made on the brickwork, and a layer of picked oakum laid on this bed from two to three inches thick; the water ring is then laid upon this. This ring (Fig. 41) is somewhat similar to a bricking ring, but has two upright projections so as to form a channel all round the shaft for the water. The bricks are laid behind this channel.

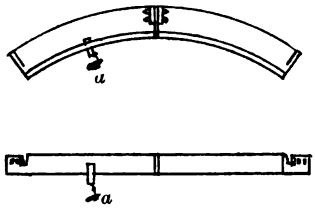


FIG. 41.—Water Ring.

Another form of water ring is that in which the inner projection is dispensed with, and the bricks are simply set back the distance required on the ring. In this form of ring, special provision has to be made at each end of the segment for the water to pass from one segment to another. Having carefully laid this ring, the lining is proceeded with, care being taken that the back course, or backing, is not made water-tight, for the water is allowed to make its own way down the back of the lining to the ring. An outlet (*a*) in the ring conveys the water down a pipe in front of the brickwork into the hoppet or other lodge room. It should be noticed that the inside edge of the

water ring should always be laid in line with the brickwork below it. In other words, the smallest diameter of the water ring should be equal to the inside diameter of the brickwork. As the brickwork is set back on this ring, it follows that the diameter of the lining at this point is larger than its diameter lower down. This brickwork is brought to its right position again by gradually drawing each succeeding course slightly inwards until the true diameter is reached. Four to five feet in height should be sufficient for this, but some engineers prefer to get back to the true diameter at the ring above.

The Poetsch Method of Sinking.—In order to overcome the difficulties of sinking through quicksand, the **Poetsch method of freezing** is sometimes adopted. In this method a freezing mixture is produced on the surface by means of a Carré ammonia freezing apparatus. In the process of converting liquid ammonia into vapour a great amount of heat is absorbed, the consequence being that the freezing mixture, consisting of a solution of chloride of calcium, is reduced greatly in temperature. By means of a number of pipes let into the ground, into which the freezing mixture is run, a large zone of quicksand in and around the shaft is hardened or solidified. The chloride of calcium is forced down an inner pipe by means of pumps, finding its way back again from the bottom of the pipes up an outer pipe to the surface, where it may again be used. The pipes are placed at distances varying from one to four feet from each other. If possible the outer pipes are first forced down to the solid strata, the lower end being then closed by means of a plug, which is covered with pitch and cement to make it water-tight. Picks, chisels and hammers are used to excavate the frozen strata, but no explosives are used, and care is taken to cause as little damage to the sides of the shaft as possible. If the freezing has been sufficient, a thick wall of strata will be formed on each side capable of resisting side pressure until the tubbing can be completed.

Raising Water.—Where a coal estate is bounded by faults, or other marked boundaries which serve to isolate the supply of water, that is to say, to confine it to the area between the faults or other barriers, it is as a rule possible to drain off the whole of the water supply by means of large pumps while the sinking is being proceeded with. This water being thus

disposed of, a comparatively small supply will remain to be dealt with, and smaller pumps or water tanks will be found adequate. On the other hand, some coal estates are so situated as to drain the water from vast areas, providing a supply which is practically inexhaustible, and necessitating the continual use of large pumping installations. Water may be raised either by pumping or winding.

Winding water by means of **hoppets** is only suitable where small quantities are encountered. It is sometimes unnecessary to wind water during the day time, the small quantity which collects being easily wound during the night, or, unless continual shifts are worked, at any time when the sinkers are out of the shaft. In this case a hoppet, or water barrel, having a valve at the bottom, is lowered into the water, filling itself owing to the valve being uplifted as it is lowered through the water. On lifting the hoppet the valve closes, and the water is allowed to run into wooden water pipes on reaching the surface, and thus conveyed to the reservoir or water course.

Galloway's Winding Tank.—In Figs. 42 and 43 is shown Prof. Galloway's excellent arrangement for winding water, by means of an automatically filled winding tank (*k*), from a collecting tank (*c*) which may be placed on supports near the lowest water ring, and is capable of being easily lowered as required. A winding engine and drum (*a*) are placed on one side of the shaft together with two hand cribs (*b*) with their barrels, upon which the spare parts of the guide ropes are coiled. The winding rope passes over the large pulley and the guide ropes over small ones at each side of the former. The collecting tank is lowered, as required, to its new position lower down the shaft by engaging the hook of the winding rope in the rings of two chains, attached to lugs one on each side. It is first lifted off its supports ; these are removed, and the tank is then lowered on to supports made ready for it, the guide ropes being uncoiled from the barrels of the hand cribs simultaneously. They are then tightened up. The ends of the guide ropes are attached to the bottom of the inside of the fixed tank, so that the winding tank may pass right in ; but in order to prevent the winding tank from coming against the bottom of the fixed tank, the former is provided with a bow underneath. If necessary the pipe (*d*) conveying the water from the water rings may be lengthened.

The **winding tank** (Fig. 43) is provided with four shoes which project from its sides and run on the guide ropes. The latter

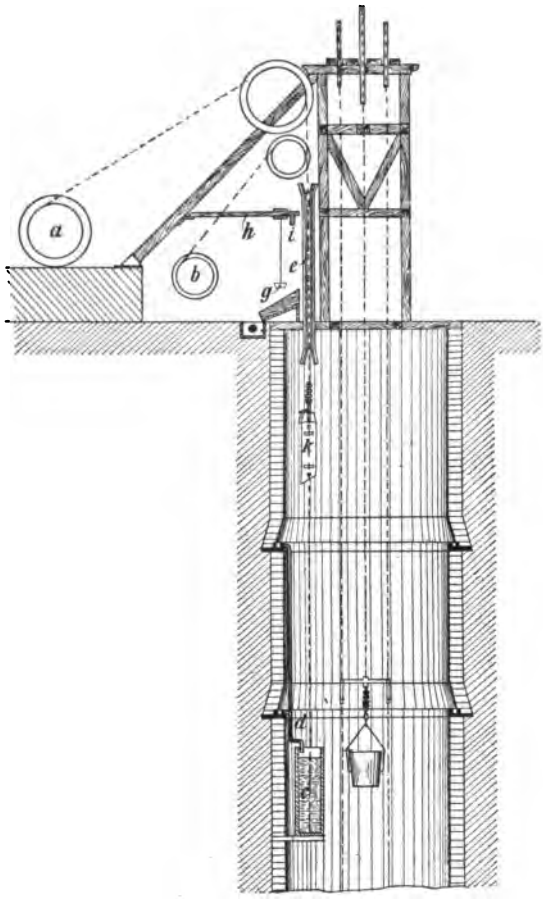


FIG. 42.—Winding Water by means of Storage Tank and Galloway's Winding Tank.

lie in the grooves of two fixed guides (*e*, Fig. 42) at the surface, each formed of two pieces of angle iron riveted to plates,

and secured at the top and bottom as shown. On reaching the surface, the guide shoes (*f*, Fig. 43) pass into the grooves referred to, and the tank is drawn upwards until the lever (*g*, Fig. 43) comes into contact with the free end of a hinged lever (*i*, Fig. 42) resting on the beam (*h*, Fig. 42), and held down by the weight (*g*, Fig. 42). Thus the progress of the lever (*g*, Fig. 42)

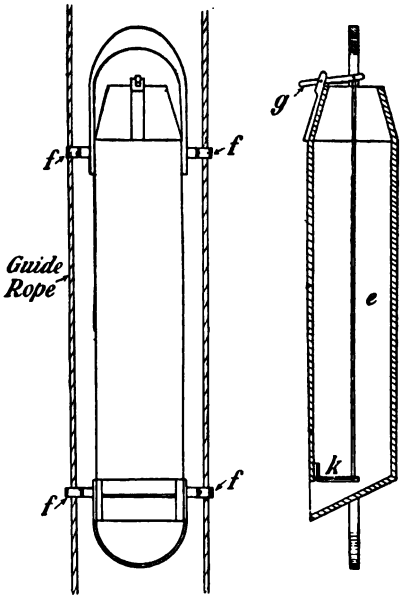


FIG. 43.—Galloway's Winding Tank.

is arrested and the valve (*k*, Fig. 43) opened by the rod (*e*, Fig. 43), the water thereupon escaping down the shoot into the drain.

Such a method of winding has great advantages which will be referred to later, and a large quantity of water can be wound in this way from any depth, the amount being only limited by the capacity of the tanks and the strength of the winding engine. Winding may proceed during the day shift or the night shift, or continuously during the whole 24 hours. With

large tanks and strong winding engines as much as 20,000 or 25,000 gallons per hour could be raised from say 200 or 250 yards.

A **Water Tank** (Fig. 44) also designed by Prof. Galloway is now used in many sinking pits. It consists of a cylindrical

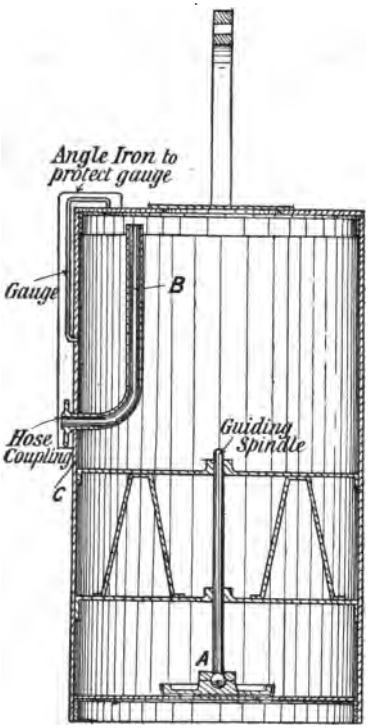


FIG. 44.—Galloway's Vacuum Water Tank.

barrel 8 ft. high and 4 ft. diameter. In the bottom of the barrel is fitted a valve (*A*), through which the water enters and fills the barrel, a vacuum having been created by air pumps at the surface. These air pumps are connected to the barrel by means of 3 in. pipes. The bottom portion of the pipes consists of flexible hose, which is coupled to the side of barrel.

Inside the barrel this pipe (*B*) passes to within an inch of the top. When the vacuum is created the water rises in the barrel, and can be observed through a glass shutter. The barrel is then raised to the surface and emptied. Storage tanks may be used in conjunction with these barrels, the tanks being suspended at convenient places in the shaft, and shaped so as to occupy as little room as possible. The water barrels are lowered to them and filled as before described.

Advantages of Winding Water.—From the foregoing descriptions it will be seen that it is not always necessary to have pumps in sinking shafts, even though the amount of water to be raised is large, and it is not difficult to realise that the methods described, or any others which are adequate to deal with the amount made, have many advantages. The first cost and maintenance is very low compared with that of pumps; the system is elastic and economical in power, fittings and attention, whether in a shallow shaft or a deep one, or whether used for winding large or small quantities of water; there is no duplication or triplication required as in the case of pumps; in the case of a great inrush of water, the apparatus and power are still available for relief; injury to shaft lining is avoided, this being impossible where bearers are required at regular intervals for pump pipes; it is an easy matter to change the winding and collecting tank should they at any time require to be substituted for others of larger or smaller capacity.

Pumps.—There are many good forms of pumps suitable for delivering large quantities of water when met with during sinking. As the water often contains large quantities of sand, it is generally found necessary to adopt ram pumps. A description of the various types of pumps will be found in a later chapter, but it may be mentioned here that the following are among the best forms of pumps for sinking: The *Pulsometer* (Fig. 56), the *Pearn Duplex Pump*, *Tangye's*, *Denaby Main*, *Davey's Evans'* pumps, and many good forms of electric pumps.

Lighting the Shaft.—The Electric Light is a very common, and certainly the most efficient, light for sinking shafts. This is suspended by means of an armoured cable capable of safely carrying its own weight and that of the lamp. The cable is wound on a small drum placed in charge of the head browman

at the pit top. The lamp may thus be raised before the shots are fired at the bottom of the shaft and lowered again after the shots have been fired. Lamps of 50 or 100 or more candle power may be used.

Ventilation.—Sinking pits are generally ventilated by

1. Small fire or steam jets and "brattice" boards, or
2. Fan and air pipes.

In the former method a small fire is suspended in the shaft, or a steam jet is used, which causes a current of air to flow behind boards fixed down one side of the shaft called **brattice boards** or through **wooden pipes** to the bottom of the shaft and thence up the shaft to the surface. Whether bratticing or pipes be used, considerable space is occupied, and it is necessary to put cross-pieces into the brickwork fairly often to support them, and strong hooks are necessary to keep them in position. If a small **Schiele** or **Cappell Fan** be used, of a diameter of three to four feet, with air pipes of 18 in. diameter, a large supply of fresh air can be obtained. These small fans are now often adopted, as there is generally some purpose to which they can be put after sinking operations are finished. Two shafts are now sunk together, and it is an easy matter to fix up a fan between them and exhaust or draw the air by the fan up two sets of pipes, both shafts being thus ventilated at the same time. Should one of the shafts be stopped the whole of the current can be easily turned into the shaft still at work. Small Shiele fans driven at a quick speed will discharge 10,000 to 30,000 cubic feet of air per minute, which is ordinarily quite sufficient to produce adequate ventilation in two shafts.

In ventilating a shaft which passes through several seams of coal giving off gas, it is necessary to take extra precautions. If a mouthing, or entrance, into the seam has been made at any of the seams, it is a good plan to turn a small supply of air into it from the air pipes. This disturbs the gas, sets it in motion and causes it to enter the shaft, where it may be carried to the surface by the returning air.

Speaking generally, if a sinking shaft is in a cool condition all the way down, it is best to exhaust the air up the pipes, the cool air thus naturally descending, a good current being produced, which carries away gases and smoke from explosives

more quickly. If the shaft is warm, owing to escaping steam from pipes, then it may be preferable to force air down the pipes.

If two shafts are being sunk simultaneously and connections made between at intervals, a simple and effective method is to make one open shaft the downcast and the other the upcast, while below the road connecting the shafts the air may be carried either up or down by means of pipes, the air being split in the downcast at the connecting road.

Costs relating to Sinking.—It is usual to keep the cost of the sinking proper distinct from any surface work or erections, beyond one or two banksmen who are engaged directly in attending to the hoppet and to the sinkers. Usually the work is let to a contractor, who undertakes to sink the shaft and to line it complete for a certain sum per yard, and an allowance for water which may have to be wound beyond about 10 gallons per minute. Allowance is also made for the putting in of water rings and for sinking through the surface clay. Very often the contract only commences after the solid has been reached. The price per yard varies according to the diameter of the pit, the nature of the ground, the prevailing rate of wages, and the quantity of water met with. This last factor is one of the most expensive extras to be considered. The cost of the material used is not charged upon the contractor, but he is expected to provide his own tools and explosives.

Accidents in Sinking.—Many of the sources of accidents have been mitigated or entirely overcome in recent years, but sinking still remains a somewhat hazardous and dangerous occupation. The handling of explosives, the risk of falling materials in the shaft, the possibility of outbursts of water and gas, the occasional accidents to hoppets and scaffolds, all tend towards this.

The use of the electric light and the employment of electric shot firing have reduced the risk in handling and firing explosives. The adoption of the Galloway scaffold has given some protection to the men from falling materials. The rods which suspend the scaffold have also minimised the hoppet and scaffold accidents. Improvements have been made in the substitution of bows and a safety hook for the hoppet chains. The folding doors are quicker in action than the travelling banking waggon, and are thus a better protection for the pit top. Non-twisting

locked coil winding ropes, such as those made by Elliot of Cardiff, reduce the risk and are of great service, and the safety detaching-hook (p. 218) should be used in all cases.

The very best material, workmanship, and attention should be given to every detail in connection with sinking shafts. When this is done, and the whole of the special rules for sinkers kept constantly in mind and rigorously observed, the accidents during sinking will be reduced to a minimum.

Questions on Chapter V.

1. Describe the mode of getting out, by ordinary hand tools, the ground from a sinking pit after the solid has been reached.

2. Describe a method of sinking by means of sinking frame and power drills.

3. How would you prepare and fire a number of shots at the bottom of the shaft?

4. Describe the Galloway method of winding and banking the debris from a sinking pit by means of scaffold, guides, and folding-doors.

5. Point out briefly the different modes of supporting loose and difficult ground when sinking. Indicate their different advantages and disadvantages. (1903.)

6. Describe the method of lining a shaft with brickwork and the chief appliances used. (1901.)

7. Describe with sketches the method of "piling," "spilling," or "forepoling" through loose ground. (1901.)

8. Describe the method of sinking and securing a deep shaft by means of tubbing. What rules have been proposed for determining the thickness of tubbing in proportion to the depth, and how do such rules compare with the dimensions actually adopted? (1898.)

9. A large sinking shaft 200 yards deep is troubled with an inflow of 20,000 gallons of water an hour. How would you raise this water? Explain fully with sketches. (1902.)

10. What accidents are likely to occur during sinking, and what steps should be taken to avoid them?

CHAPTER VI.

WORKING.

THE seam of coal it is proposed to work having been reached, new tools and appliances will have to be used, and a variety of methods adopted to extract the coal. Before any large quantities of coal are got, very important operations—including the setting out of the shaft bottom, and the driving of the main haulage and air roads—will have to be carried out.

Before describing these operations and the tools used in performing them, it is necessary briefly to describe the character and qualities of the various seams of coal and the rocks associated with them. As has been said, coal seams are found interstratified with beds of shales and sandstones, and to assist the miner in recognising the stratified rocks he may meet with in sinking, tunnelling or getting the coal, the following classification of them is given :

STRATIFIED ROCKS.

- I. Mechanically Formed (Sedimentary or Fragmental), - - -
  - 1. Argillaceous, -
    - Mud.
    - Clay.
    - Shale.
  - 2. Arenaceous, -
    - Sand.
    - Sandstone.
    - Grits.
    - Conglomerates.
- II. Organically Formed, -
  - 1. Calcareous, -
    - Calcareous Ooze.
    - Chalk.
    - Coral Reefs.
    - Shelly and other Limestones.
  - 2. Carbonaceous,
    - Peat.
    - Lignite.
    - Coal.

III. Chemically Formed, - { 1. Siliceous, - { Ganister. Flint. Chert. Sinter. } 2. Calcareous, - { Calcareous Nodules and Concretions. }

The stratified rocks of the first and second of the above classes are those commonly met with in mines, namely, the Argillaceous, Arenaceous, Calcareous and Carbonaceous. These rocks differ not only in appearance and structure, but in hardness and in the frequency with which joints or cracks occur. The hardness of a formation and the frequency with which joints occur are characters of great importance to the miner.

Argillaceous Rocks, such as shales, clods, "blue metal" and clays, can easily be broken up with pick and shovel, and offer no great difficulty to the miner during excavation; when, however, they form the roof or floor of a seam, they are a source of great trouble and danger, breaking up when exposed to the atmosphere and needing great quantities of timber to keep them up.

Arenaceous Rocks, such as sandstones and conglomerates, are hard and compact as a rule, and are generally referred to as "metal." They are difficult to excavate even with drills and blasting arrangements, but they form good roofs, being less liable to break up than the argillaceous rocks and containing few fractures or breaks.

Calcareous Limestones and argillaceous limestones, formed where clay has been deposited with calcareous matter, are often hard and unyielding rocks. Many shafts in Lancashire have been sunk through rocks of the former class for considerable distances, which have proved exceedingly hard to work, but have formed a good and secure shaft. When the coal roof is composed of such limestone, little difficulty is experienced in supporting it. Limestone mixed with coal is frequently found lying at the roof of a coal seam, and is called **brat**.

Carbonaceous Rocks, such as coal seams, bands of inferior coal or **bass**, and **warrant**, are not as a rule so hard as arenaceous or calcareous rocks, being composed chiefly of vegetable matter, either in the form of coal or mixed with clays and shales in the form of bass, warrant or buzzard. A carbonaceous roof is generally a good roof, being more consistent than a clod roof, but not so strong as a metal one.

A few of the above rocks may be still further described as follows:

Sandstone is composed of small grains of quartz of varying sizes cemented together by silica, calcium carbonate, or some other cementing material, to form a compact and hard rock.

Clay is a more or less plastic substance composed of fine particles of minerals and rocks, such as felspar and other silicates, which have been worn away by water or by weather. Clay is almost impervious to water, that is to say, it does not allow water easily to pass through it, and consequently is used for puddling, dams, etc. Large volumes of water are often held by water-bearing strata, owing to the occurrence of a bed of clay below them. Clay is easily moulded into various shapes, and, as it will also withstand great heat, it is used for making bricks.

Shale is hardened clay or mud. It generally splits up into thin plates or laminae, parallel to the plane of stratification. This laminated structure is due to the deposition of the particles under water. As they often contain traces of vegetable matter, they are dark coloured as a rule.

Marl is a soft mixture of clay and calcareous matter, such as chalk or limestone, and is used by farmers for enriching soils exhausted of lime.

Loam consists of a mixture of clay and marl; it is less plastic than clay, and pervious to water.

Coal seams not only vary in their chemical composition, but in their thickness, structure, hardness, and the number of **breaks, slips, cleats,** or **faces** contained in them. It is necessary to become acquainted with all these different features of coal seams before deciding upon the method of removing the coal.

Lamination.—Owing to the deposition of coal under water, the seams are generally made up of a number of thin plates or laminae, which are parallel to the plane of stratification. This horizontal division is more marked in some seams than in others, being as a rule very distinct in Lignites and Bituminous Coals, but entirely lost in Anthracites.

Cleat or Face.—The various joints or faces in a seam of coal are not all equally distinct. The most distinct vertical joint is called the cleat or face. A second but less marked vertical joint is generally found either at right-angles to the face or at angles slightly more or less than 90°. These joints cause the

coal to be broken up into rhomboidal blocks. According to M. André, the occurrence of this cleat in coal seams is due to its shrinkage when drying.

End.—The second or less distinct joint forms the end of the coal, and, as the cleat is generally parallel to the strike, or level, of the mine, a seam worked at right-angles to this is said to be worked **on the end.** A seam worked at an angle midway between face and end is said to be worked **Half End and Face.**

Dip.—The angle which the beds make with the horizontal plane is known as the **dip.**

Strike.—The line at right-angles to the plane of dip, along the level of the seam, is known as the **strike.**

Tools and Appliances for Excavating by Manual Labour.

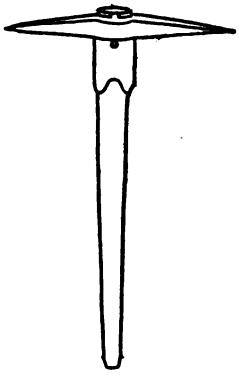


FIG. 45.—Miner's Pick, "Universal."

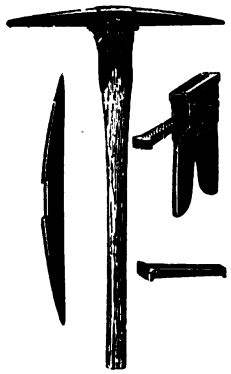


FIG. 46.—"Acme" Pick.

Picks.—The miner's pick consists of an iron or cast steel head or blade, 18 in. long, fitted on to a headed shaft of hickory wood or ash, from 32 in. to 42 in. long, and weighing from 1½ to 3 lbs. in the case of the blades; the handles are of 2 or 2½ lbs. The blades are either straight or curved, and sharpened at both ends. The lighter picks are used for deep undercutting and the heavier for the tops; for stone work, picks weighing 6 or 7 lbs. are used. The most common forms of picks are those made by the Hardy Patent Pick Co., and called the Universal (Fig. 45) and Acme (Fig. 46) respectively. The

last named is provided with sockets, wedges and keys for fastening the head to the shaft, but for simplicity and effectiveness few picks are better than that shown in Fig. 45, the blade being tightened on to the shaft by merely knocking the head against the floor. Each collier provides himself with several blades daily, according to the hardness of the coal or dirt he is occupied in undercutting, or in "holing" as it is termed.

Shovels.—Various forms of miner's shovels are in use, the majority being of the round-mouthed shape (Fig. 47), made of hammered steel with ash handles. The width of the shovel proper is generally about 12 in., the length being the same.

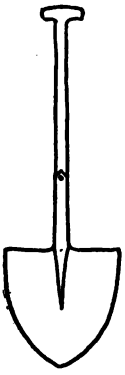


FIG. 47.—Miner's Shovel.

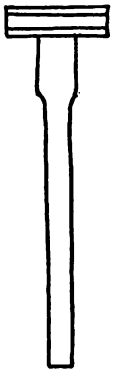


FIG. 48.—Hammer or Mall.

Hammers or Malls.—These, for driving in wedges or for tightening timber, are used by every workman. The heads (Fig. 48) generally weigh 4 or 5 lbs., and are made of iron with steel facings, the broad end being about 2 in. square and the length of the head about 6 in. A large face on the hammer and a small face on the wedge is the most effective means of concentrating the blow.

Scraper, Pricker, Tamping Rod.—These appliances are used in connection with shot firing. In consequence of many serious accidents during the charging of shots, owing to the employment of iron or steel appliances, all the above are now made of copper, and even these can only be considered safe when great care is taken in their use.

The **Scraper** consists of a long rod of copper with a circular disc about the size of a halfpenny formed at right-angles to the rod at one end, and a scooped handle at the other. It is used to clean out the hole after boring or when changing drills; this procedure being also necessary before it is safe to insert the explosive.

The **Pricker** is a copper rod about 3 feet long, used in those mines (happily steadily diminishing) where the old form of igniting shots by means of straws, etc., is permitted. It is provided with a point at one end, and this is pushed into the cartridge, which is then lifted into its place in the hole. The pricker remains in this position until the stemming is completed, and on being steadily withdrawn leaves a hole through which the explosive may be ignited by straw or fuse.

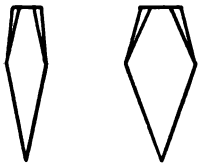


FIG. 49.—Wedges for Coal or Rock.

The **Tamping Rod** or stemmer, made of wood or copper, is a simple rod having a groove cut along its surface into which the fuse is fitted as it lies in the hole, and enables the rod to be used to charge and tighten the shot without danger of damaging the fuse.

Wedges.—Small iron wedges (Fig. 49) weighing 5 or 6 lbs. are used for getting down portions of rock or coal, or breaking the same after they have been shattered by explosives. The thin end of the wedge is driven by a hammer into the coal or rock to be broken, the thickness of the wedge being determined by the hardness and elasticity of the coal.

Hand Drills.—As a great portion of the miner's time is occupied in drilling holes for shot firing, it is necessary that a good and efficient drill be used. In soft coal, hand drills are used, but are gradually giving way to machine borers. The hand drill consists of a long iron octagonal rod, called a **jumper**, with a broad chisel edge at one end sharpened according to the nature of the rock or coal, and weighted between the two ends by what is called a *bead*—an enlargement of the rod. In drilling holes in the coal or roof this weight is necessary, but in boring holes in sinking pits the bead is not needed, the drill being made 10 or 12 feet long, with making up pieces, and this gives weight sufficient for drilling even in very hard rock. The miner turns the tool at each stroke of the drill, holding

it with both hands and twisting it round, every now and then clearing out with a scraper the debris accumulating in the hole.

Hand Machine Drills.—There are so many cheap and exceedingly handy machine drills that most colliers are now provided with them, and the hand drill is now seldom used. Drills may be divided into two classes, those which drill the hole by (1) Rotation, (2) Percussion. In the former a regular circular motion is given to the drill, by means of which the coal or rock is gradually worn away, the debris being slowly worked back from the bit or cutting end of the drill to the front of the hole, the drill thus clearing itself as the hole progresses.

In the second method the hole is bored by means of a cutter, which gives many short sharp blows at the coal or rock, chipping off small pieces of the same, and in some cases arranged so as to clear out the debris from the hole. This clearing is not so easy to accomplish, however, by this method as by the former.

In the first method the rotary motion is generally given to the tool by means of a screwed spindle or worm, turned by means of a ratchet handle attached to the end through a stationary nut. Into the opposite end of the worm is fixed a suitable drill, which rotates and grinds against the stratum when the ratchet handle is worked, gradually advancing as the worm or spindle moves through the nut. The "pitch" of the worm is regulated according to the nature of the material, and in addition to this the feed is automatic, that is to say, the speed is slower, but the labour lighter, where the rock is most difficult to penetrate.

The following are some of the Hand Machine Drills at present used by colliers:

1. **Rotary Drills.**—*The "Little Tiger" and "Acme" Boring Machines.*—These machines, weighing about 30 or 60 lbs. respectively, are suitable for coal and *bind* (shale or clay ironstone forming the roof of seams) and for holes of small diameter. The handle, which is behind the stand, is turned through a complete circle, thus drilling the hole more quickly than if only a partial circular movement was possible. In hard ground this is impossible, and other means have to be adopted.

The Elliot Boring Machine (Fig. 50) is designed for hard coal and rock. It is a very efficient rotary drill, and is readily fixed up at the face, having a stand which can be extended almost twice its length if necessary. In order to ensure strength as well as lightness, the parts likely to become strained are made of steel. The drills are readily changed, a few turns of the handle shown next the face being required to unhook the drill, which is then racked back and lifted out of the hole. The feed is automatic, thus avoiding risk of breaking the bits or cutters, or putting undue labour upon the person operating the machine.

FIG. 50.—Elliot Boring Machine.

The "Ratchett" Boring Machine.—This machine (Figs. 51 and 52) is suitable for very hard coal or rock, or where a large hole is required. Although described last, it has been in use longer than the two machines described above. A stand is not used with this machine, a timber prop being required to be set at a convenient distance from the face, against which the point at the end of the barrel is placed, and the worm screwed outwards, until the point of the drill is touching the coal face at the place chipped out for the hole. A few short

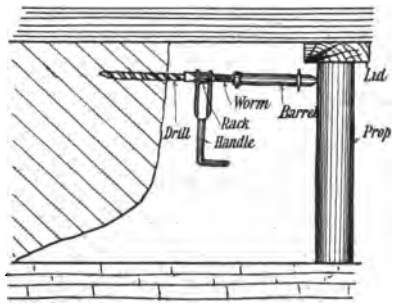


FIG. 51.—"Ratchett" Boring Machine; fixed.

movements of the handle then tightens the whole machine, and the actual drilling is commenced. As will be seen from the sketch, the handle, unlike the handle of the *Elliot* and *Acme*, is placed between the drill and the barrel. Like the others, the drill is withdrawn after boring its own length, and the next length of drill inserted, three changes being generally necessary in a hole of 4 feet. The question of the ease with which the drill clears out the debris depends more upon the form of bit and drill than upon the form of machine. A sharp and good form of bit may be obtained and the hole for a time drilled rapidly, but if the drill is too large in diameter, or too small, or if the rate of twist of the drill is not suited to the size, then the sides of the drill will be found to rub against the sides of the hole, the debris will become clogged, and extra labour will be necessary to rotate the tool. On the other hand, the best size and form of tool may be used, and no difficulty be found in clearing out the debris, but if the form of bit is not the best, or the point is not quite sharp, the cutting will be slow.

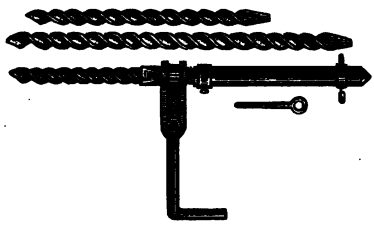


Fig. 52.—"Ratchett" Boring Machine.

The "Broad V" form of point is the most suitable for hard rock, ordinary rock, bind and coal; it penetrates easily and quickly, and is simplest to repair. The piece cut out of the centre should be a little more than one-third of the full width of the point and of a broad V shape, in order to keep the two outside portions as strong as possible. These portions should be kept as thick and stiff as the section of the steel used will allow; it is unwise to draw these down thin. The cutting point should be carefully attended to; it should be kept sharp, and a good clearance at the back be left. As a rule, the wider the V the more rapidly will the drill penetrate, especially in coal or shale, but the size of this opening will be determined by the miner after due experience, as it may be necessary to reduce the size of the opening in harder coal.

2. **Percussive Drills.**—*The Elmore Hand Rock Drill* is a hand-power reciprocating machine, capable of drilling holes with less exertion on the part of the operator than is obtained with the ordinary single-hand method. It is a percussive drill delivering 80 to 100 blows per minute, the weight of the blow said to vary from 100 to 500 lbs., is regulated according to the nature of the material to be cut. The action is as follows: The first part of the stroke of the handle compresses a spring acting directly on the bit which it withdraws from the bottom of the hole, and rotates the bit though an angle of 45°; the second part of the stroke releases the spring, which forces the bit to the bottom of the hole, and sets a sledge hammer which is fitted at the end of the machine farthest from the coal. The third and last part of the stroke releases the hammer, which strikes a heavy blow at the drill. For soft material the hammer is dispensed with, the blow being struck by the spring.

Explosives.—An explosive is a substance which is capable of being suddenly transformed into gases on the application of heat. These gases, which occupy a much greater space than the original substance, exert a certain force upon any surfaces which tend to confine them. This force is dependent not only upon the gases produced, but also upon the heat generated owing to the chemical action which takes place. In the case of an explosive, however, this force must be developed rapidly, that is to say, the combustion and decomposition of the substance must take place instantaneously; the result is that when such substances are confined in closed spaces and ignited, the great volume of liberated gases exerts such an enormous pressure upon the sides of the confined space as to shatter and break them down, thus causing an explosion.

In the case of a **Mining Explosive**, the above qualifications are not in themselves sufficient. It is necessary that the explosive should fulfil other requirements besides that of being capable of sudden transformation into gases on the application of heat. Many explosives, which decompose rapidly and with great expanding power, are altogether unsuited to mining work because of their dangerous qualities before, during, or after firing.

A Mining Explosive must be

(1) safe to store and handle,

(2) must require a fairly large amount of heat to produce decomposition,

(3) must detach but not unnecessarily shatter the coal,

(4) the products of combustion must be non-combustible and non-poisonous, and

(5) the heat generated by the chemical action accompanying decomposition must be as little as possible.

Classification of Explosives.—Explosives are either mixtures or compounds, that is to say, the constituents are either mixed carefully together mechanically or combined chemically. In either case, it is necessary that they should consist of at least two substances, one containing a large percentage of oxygen, the other being highly combustible. The particles, whether in the form of a mixture or a compound, should be held together loosely, so that on the application of heat the oxygen may combine at once with the combustible substance without loss of time or heat.

Gunpowder Class.—Gunpowder, which was one of the first explosives ever used, is a mechanical mixture, its composition being :

Potassium Nitrate, - - - - -	75
Sulphur, - - - - - - -	10
Charcoal, - - - - - - -	15
	100

The potassium nitrate, which contains a large proportion of oxygen, is intimately mixed with two combustible substances, the result being that on the application of heat the oxygen is at once liberated, joining with the other constituents and forming large volumes of gaseous products. The heat required to accomplish this is not great, but the chemical action which results causes a great increase of temperature, the expansion of the gases being greater or less according to the heat thus caused. It will not be difficult, therefore, to understand that where this heat is sufficient to ignite either the combustible solid products of the explosion, or the firedamp or coal dust present in the atmosphere, these may easily be ignited. As the products of an explosion of gunpowder are often combustible, and the heat generated very great, a flame is often produced which, in mines, is of great danger. It is for this reason that gunpowder in its simple condition is a prohibited explosive in a large number of mines.

Blasting Powder consists of the same constituents as gunpowder in different proportions:

Potassium Nitrate, - - - -	65
Sulphur, - - - - - -	20
Charcoal, - - - - - -	15
	100

It was designed to obtain the same expanding power at a lower temperature of explosion. This is secured, but as the products of combustion are exceedingly inflammable, being chiefly carbon monoxide, it is a dangerous explosive to use in coal mines, as it is evident that the composition of the gaseous products of the explosion is as important a factor in determining the safety of an explosive as the amount of heat produced during the explosion. A certain amount of heat is required to ignite mixtures of firedamp and air, but less heat may be necessary to ignite the mixtures if traces of carbon monoxide are present.

The following table shows the products of combustion of Gunpowder and Blasting Powder:

GASEOUS PRODUCTS OF COMBUSTION.

	Gunpowder (Fine Grain).	Blasting Powder.
Carbon Dioxide, - -	50·62	32·15
Carbon Monoxide, - -	10·47	33·75
Nitrogen, - - - -	33·20	19·03
Sulphuretted Hydrogen, -	2·48	7·10
Marsh Gas, - - -	0·19	2·75
Hydrogen, - - -	2·96	5·22
Oxygen, - - - -	0·08	0·00
	100	100

As already stated, a mining explosive should possess qualities not found in gunpowder. Many explosives now possess certain of these good qualities, but in order to understand fully how the change has been brought about it will be necessary to give a short history of certain classes of explosives which have been instrumental in increasing, to a certain extent, this safety; but before proceeding to describe the various explosive compounds known as **High Explosives**, it will be necessary to say a few words about the mode of igniting them by *detonation*.

Detonation.—While making experiments with explosives, Nobel found that certain compounds, the first being Nitro-Glycerine, exploded with great violence and effect when fired by means of a detonating fuse which produced a sharp explosion, with vibration and heat of a peculiar kind. This was owing to the instantaneous decomposition of the explosive by means of detonation. It is well known that certain compounds, such as Fulminate of Mercury, Fulminate of Silver, Iodide of Nitrogen, etc., the elements of which are held loosely together, will decompose readily on the application of a small amount of heat. When this decomposition takes place in the detonator a series of heat-waves are set up, which, being brought in contact with certain explosive compounds, have the power of shattering or shaking apart their elements, and thus liberating large volumes of gases which produce an explosion. It is necessary that the amount of Fulminate of Mercury in the detonator shall be sufficient to produce an *initial shock* capable of eventually decomposing the whole of the explosive, and as all explosive compounds do not require the same initial shock, detonators containing various weights of detonating substance are manufactured. The composition of this substance is generally as follows :

Fulminate of Mercury, - - - -	80
Chlorate of Potassium, - - - -	20
	100

The detonators are numbered according to the amount of this mixture which they contain, thus :

Detonator	No. 1	contains	4·5	grains.
„	2	„	6	„
„	3	„	8	„
„	4	„	10	„
„	5	„	12	„
„	6	„	15	„
„	6½	„	19	„
„	7	„	23	„
„	8	„	30·9	„

Nitro-Glycerine Class.—Nitro-Glycerine was the first explosive compound ignited by detonation, consequently it marks an important step in the progress of modern explosives. It consists of Nitric Acid, Sulphuric Acid and Glycerine, and, when

these are mixed together in right proportions and fired by detonation, forms a powerful explosive which gives off large volumes of gaseous products; but owing to its great liability to explode unless carefully stored and handled, and the fact that it too readily freezes—its freezing point is 46°—it was useless as a mining explosive until Nobel conceived the idea of mixing with it certain quantities of explosive or non-explosive substances, which absorbed the nitro-glycerine and formed compounds which were not so sensitive to shock, such as Dynamite.

Dynamite is composed then of Nitro-Glycerine and an absorbent substance such as Kieselguhr. Mixing this earthy substance with the nitro-glycerine renders the explosive less liable to sudden decomposition, and in many cases forms a more powerful explosive, but like other explosives of the nitro-glycerine class, such as *Blasting Gelatine* and *Carbonite*, the products of combustion are inflammable and consequently dangerous. The following are the compositions of other nitro-glycerine compounds:

I.—TABLE OF SOME NITRO-GLYCERINE COMPOUNDS INCLUDED IN PERMITTED LIST.

Carbonite—	
Nitro-Glycerine,	26
Nitrate of Barium or Potassium,	33
Wood Meal,	35
Moisture,	5
Sulphuretted Benzol,	½
Carbonate of Sodium or Calcium,	½
	100

Fired by Detonator No. 6.

Nobel Ardeer Powder—	
Nitro-Glycerine,	32
Kieselguhr,	12
Sulphate of Magnesium,	49
Nitrate of Potassium,	6
Carbonates of Ammonium and Calcium,	1
	100

Fired by Detonator No. 3.

These two compounds are now considered sufficiently safe to warrant their inclusion amongst explosives which have passed the Special Test of the Home Office. Consequently it must be inferred that in case of some, at any rate, the combustible

products have been reduced, while in others the heat generated during explosion is not high.

The products of combustion of Carbonite are:

Carbon Dioxide, - - - - - - -	19
Carbon Monoxide, - - - - - -	15
Hydrogen and Marsh Gas, - - - -	26
Nitrogen, - - - - - - - -	40
	100

As there are quantities of inflammable carbon monoxide, hydrogen and marsh gas formed, it follows that there will be considerable danger unless the heat produced is low.

Sprengel Explosives.—This class of explosives consists of those containing potassium or ammonium nitrate mixed with certain hydro-carbon substances such as benzene, naphthalene, wood-meal, etc., the elements of which are in such a condition as to render them easy of combination with the oxygen of the potassium or ammonium nitrate. These mixtures are found to be not only safe to handle in consequence of their high detonating point, but the products of combustion are as a rule non-inflammable and of a low temperature; but this can only be the case where all precautions are taken. Sprengel explosives are designed to produce few inflammable products, and to give off little heat in their decomposition. The absence of inflammable products is said to be due to mixing the constituents so as to ensure complete combustion of the inflammable gases, leaving only *carbon dioxide*, *nitrogen* and *water vapour*.

In this class are placed such explosives as *Ammonite*, *Electronite*, *Bellite*, *Roburite*, etc. They are all fired by means of detonation, and as a rule are very effective explosives. The ignition of the particles is extremely rapid, however, shattering the coal greatly, and in this way reducing considerably its commercial value.

The following are the compositions of a few Sprengel Explosives:

II.—Table of some Sprengel Explosives in Permitted List.

Ammonite—

Nitrate of Ammonium, - - - -	88
Di-nitro Naphthalene, - - - -	12
	100

Fired by Detonator No. 6½.

Electronite—

Nitrate of Ammonium,	73
Nitrate of Barium,	19
Wood Meal and Starch,	7½
Moisture,	½
	100

Fired by Detonator No. 7.

Roburite No. 3—

Nitrate of Ammonium,	87
Di-nitro Benzol,	11
Chloro Naphthalene,	1½
Moisture,	½
	100

Fired by Special Detonator containing 15 grains of

Fulm. of Mercury,	95
Chlorate of Potash,	5
	100

Bellite No. 3—

Nitrate of Ammonium,	94
Di-nitro Benzol,	5¼
Moisture,	¾
	100

Fired by Detonator No. 7.

The products of combustion of Ammonite, Roburite and Bellite are:

Carbon Dioxide,	32
Carbon Monoxide	Nil
Hydrogen and Marsh Gas,	Nil
Nitrogen,	68
	100

It will thus be seen that as there are no inflammable products given off, there is less danger than would be the case with other explosives, unless the heat generated is so great as to cause the other gases of the mine to become ignited.

Blasting.—Line of Least Resistance.—It is easy to understand that when a shot is fired in coal or rock the direction of the breakage will be chiefly in the line of the weakest part. In coal or rock of uniform strength this direction would be a

straight line from the explosive to the nearest unsupported edge. But coal seams and rocks are not of uniform strength, having numbers of breaks, cleats and faces in their structure. It follows, therefore, that the line of least resistance is not necessarily the shortest line from the explosive to the surface. When holes are bored, the collier should observe the position and nature of any breaks or faces in the coal, and should place his hole so as to take advantage of these. The depth of the holing will regulate the *depth* of the drill hole (Fig. 53); its distance from the next hole or the presence of a fast side or loose end will affect the *position*; the character and frequency of faces or breaks will decide the *direction*. In addition to these considerations, experience will teach the miner to take advantage

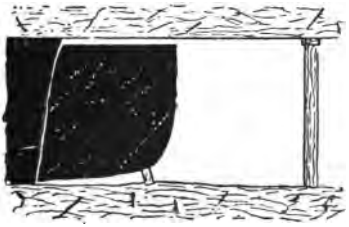


FIG. 53.—Hole drilled correctly.

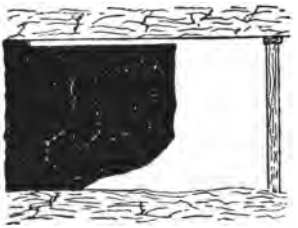


FIG. 54.—Hole drilled incorrectly forming a "Fast" Shot.

of a good parting or a strong roof, and to avoid the bad effects of drilling a hole where the force of the explosive may be reduced owing to the presence of a strong band of ironstone or even of a soft layer of inferior coal. By constant practice and careful observation a collier is enabled to determine the best position, depth and direction of a bore hole, keeping in mind that it is necessary not only to avoid "fast" shots caused by drilling the hole too deep (Fig. 54) or in the wrong direction, but that it is also essential that he should get the greatest amount of coal with as little labour as possible.

Charging Shot Holes.—Explosives for mining purposes are made up in cartridges weighing from three to five or six ounces.

These cartridges are pushed one by one to the bottom of the hole by means of a wooden tamping rod or stemmer (p. 94), care being taken not to force them into holes too small, or to use undue pressure in getting them into position at the bottom of

the hole. In making up a charge, as few cartridges as possible should be used; for example, in a charge of nine ounces it is better to use one cartridge of five ounces and another of four than three cartridges of three ounces each. It is advisable to insert the detonator in the heaviest cartridge. This is done by boring a hole through the neck by means of a pointed piece of wood. This hole should be deep enough to ensure the detonator being entirely buried in the explosive. The detonator is then inserted and the neck of the cartridge pinched by means of nippers, thus making a tight joint (Fig. 55). When used in wet holes this joint should be rubbed with grease or tar. Many explosives, however, such as Gelignites, are not affected by water, and it is only necessary to push the detonator into the semi-plastic explosive. Detonators are now supplied fitted with short wires (Fig. 56), to which an electric cable may be attached. The risk, therefore, of accidents occurring during the insertion of the fuse into the detonator is now avoided. The last cartridge with detonator attached having been placed in the hole, a little light tamping of soft clay is put in, and afterwards hard stemming may be used (Fig. 56), the amount of this stemming being determined by the nature of the explosive. With gunpowder it is impossible to do this portion of the work too carefully. With the explosives of the nitro-glycerine and Sprengel class less stemming may be used, but it is the safest plan to insert too much rather than too little.

Fig. 55.—Detonator inserted in Explosive Cartridge.

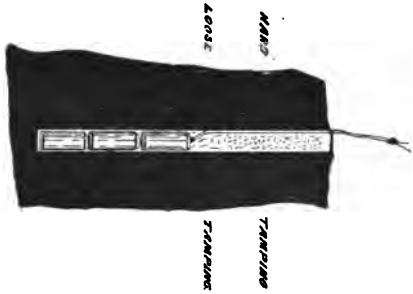


Fig. 56.—Explosive Cartridges placed in Shot Hole.

Methods of Firing.—The two chief methods of firing shots at present resorted to are (1) by means of safety fuses, (2) by electricity. Shots were fired formerly by most unsafe and inconvenient means, the best known of which was the *squib*.

Squibs, or **Germans**, were made by filling straws or paper

cones with fine powder. Touch paper, made by steeping paper in saltpetre, was also used. These were inserted into the hole formed by the pricker (p. 94), and ignited by means of a candle, snuffing wire or lamp.

Safety Fuse.—This fuse is made by wrapping a train of fine powder in a covering of tape, rope, yarn, or gutta-percha. When employed for firing gunpowder, it is first cut and then threaded through the bobbin, the end being turned on to the bare surface of the gunpowder, so that the train of powder inside is in contact with the explosive. When used with detonators the cleanly-cut end of the fuse is pushed into the detonator until the fuse touches the composition, care being first taken to remove any sawdust that may have accumulated. The detonator is then secured to the fuse by careful squeezing, and this not only prevents the displacement of the fuse, but serves to develop the full force of the detonator. Safety fuse is generally made in lengths of fifty feet and of the following grades :

Hemp Fuse, for perfectly dry work ;
Cotton Fuse, stronger and safer than hemp, but only suitable for dry work ;
Single Tape Fuse, suitable for damp but not for wet work ;
Double Tape Fuse, suitable for wet work ;
Triple Tape Fuse, an improved form of the last named.

Electric Shot-Firing.—In most mines the firing of shots is now done by means of electricity. Electric cable wires of at least twenty-five yards in length are attached to the detonator wires at one end, and at the other to small handy exploders. The exploders consist of small boxes, containing either magneto-electric machines for producing high or low tension current, or one or two batteries arranged to give a strong low tension current.

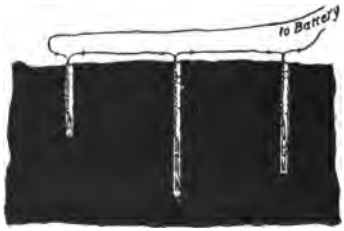


FIG. 57.—Electric Shot-Firing in "Series."

Shots are fired either singly or simultaneously. In the former case either a high or low tension detonator may be used. In simultaneous blasting the shots are fired either "in series"

or "in parallel." In series firing, the wires are coupled up as shown in Fig. 57, the cable wire being attached to one wire of the first shot, the other wire being coupled to the first wire of the second shot and so on, the second wire of the last shot being attached to the second cable wire. In this way a large number of shots may be fired together, care being taken that the exploder is of sufficient strength to give the necessary current.

In parallel firing (Fig. 58) the cable is bared at suitable points and the detonator wires are attached directly to the respective wires, but this is not so satisfactory a method as the former.

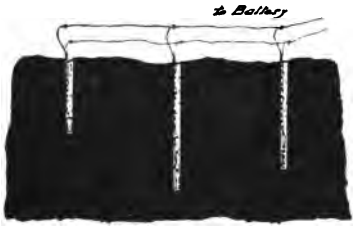


FIG. 58.—Electric Shot-Firing in "Parallel."

Detonators.—In a high tension detonator the explosion is caused by a spark jumping between two terminal points inside the detonator. In a low tension detonator the explosion is caused by the current passing through a short bridge of Iridio-platinum wire, making it red hot and firing the priming—a small quantity of chlorate of potash—which in turn ignites the fulminate of mercury. It is thus seen that a satisfactory explosion depends upon the existence of a proper electric circuit both inside and outside the detonator. This circuit may be tested in the case of low tension fuses by means of a galvanometer though the advantage gained by this is small.

Wires.—The short wires connected to the fuse are arranged as follows:

(1) High Tension Twisted Wires.
(2) High Tension Twin Wires.
(3) Low Tension Twin Wires.

These wires vary in length from thirty-six inches to sixty inches, according to the usual depth of the holes. In coupling the firing cable to these wires, great care should be taken. The fuse wires should be separated, the ends of both cable and fuse wires cleaned, and then connected by twisting carefully together (Figs. 59 and 60) in such a manner as to prevent the "lead" and "return" from coming in contact with each other.

During the whole of this operation, it is very necessary that the shot-firer should have possession of the exploder, and not until he has made the connections with the fuse wires, and retired to a place of safety, from whence he intends to fire, should he couple up the cable to the exploder terminals. Having done this, a few sharp turns of the handle, and the pressing of the button while the handle is in motion, will cause the current to pass along the wires and through the priming in the detonator, thus firing the shot. In battery exploders, the shots are fired as soon as the ends of the cable touch the terminals.

FIG. 59.—Method of twisting Cable Wires to Detonator Wires.

FIG. 60.—Method of twisting Cable Wires to Detonator Wires.

Miss-Fires.—Miss-fires during shot-firing may be caused either by carelessness in charging and firing the shot, or owing to the use of defective materials. In the latter case accidents may arise from :

(*a*) **Defects in the Explosive.**—Accidents from this cause are no doubt rare ; probably the chief danger arises from the tendency of some explosives to exude or sweat during storage. If a greater charge of explosive is used than the detonator is able to fire, some of the explosive may be left fizzing in the hole or even be unconsumed. These are two dangerous circumstances and can only be avoided by seeing that all the cartridges are placed in contact during charging, without the occurrence of pieces of dust or clay between, and by the careful selection of a sufficiently powerful detonator.

(*b*) **Inferior Detonators.**—It is easy to understand that in the manufacture of large quantities of detonators, it is not possible to avoid mistakes in the filling of them. If the weight of detonating substance is less than it should be for a certain explosive, a miss-shot may occur. But in cases where the detonator is properly filled, it may happen that the priming is not fired by the spark, or that the detonating substance is not fired by the priming.

(*c*) **Faulty Fuse or Cable.**—Where safety fuse is employed, accidents sometimes occur owing to the bad construction of the

fuse. In some cases the train of gunpowder is not perfect, and combustion may cease altogether, or travel so slowly that the charge appears to hang fire for a time, and there is then a risk of the shot-lighter returning to the shot while the fuse is still alight. With electric shot-firing this danger is avoided, and shots seldom miss-fire owing to faults in the fuse or cable, although occasionally this may occur when a weakened or unsuitable exploder is used.

Miss-Fires due to Careless Charging and Firing.—Although, as we have just said, the fuse and cable used in electric shot-firing are generally faultless in construction, one of the chief causes of miss-shots is due to carelessness in manipulating them. While the hole is being stemmed, the end of the fuse should be held in such a way that the detonator cannot be withdrawn accidentally from the charge. This would be avoided by placing the detonator in the first cartridge, but this method is not recommended. In coupling up the cable it is essential that great care be taken. The ends should first be scraped, and then after being joined (Fig. 60), it is advisable, in order to avoid "short-circuiting," to wrap the exposed wires with insulating tape. It is a good thing to use a reel for the cable, and it is also necessary that the shot-lighter should keep possession of the exploder in all circumstances. (Special Rules, Coal Mines Regulation Act.)

Blown-Out Shots.—These may be caused in the following ways:

(*a*) **Owing to the Hole being Drilled into the "Fast"** (Fig. 54), that is to say, drilled deeper than the holing, or put in such a direction flankwise, that it passes into the solid ground.

(*b*) **Insufficient or Unsuitable Stemming.**—With gunpowder it is absolutely necessary that the stemming shall be not only of the kind prescribed by the Coal Mines Regulation Act, General Rule 12, but that it shall be thoroughly well done, and made as firm as the depth of the hole and the amount of powder will allow. With the *Permitted Explosives* also it is equally necessary that the stemming should consist of clay or some other non-inflammable substance; and although the amount need not be so great as with powder, it is advisable to put in as much as will guarantee absolute safety. This stemming should be carefully done, all portions being equally well pressed in, at the top of the hole as well as at the bottom.

Various methods have been devised for ensuring the safe charging of shot holes. Cartridges of clay, made at the surface, are used for stemming, and pressed home by means of special wooden tamping rods. The effect of this plan is to get strong and evenly-stemmed charges with little risk to the operator.

(*c*) **Overcharging.**—If a shot hole is overcharged, the effect is practically the same as that caused by insufficient stemming. The amount of explosive used depends upon the strength of the compound and the work it has to do. It is only by constant practice and careful observance of the effect that a shot-lighter is able to gauge the right amount of explosive necessary for each hole.

It will be seen, therefore, that in order to avoid the many accidents likely to occur owing to premature blasting, miss-fires, blown-out shots and illegal unramming of charges, the whole of the operations connected with the firing should be most carefully and skilfully done; and the person responsible for the same should exert himself to the utmost so that he may get as much coal as possible consistent with absolute safety.

Mechanical Substitutes for Blasting.—Many mechanical appliances have been introduced from time to time as substitutes for explosives; many of these have proved ineffective; but there are one or two at present in regular use which show that explosives are not absolutely necessary, and that it is possible to get down coal or rock by mechanical means in a safe and convenient manner.

Simple Wedge.—For breaking off portions of the seam, or for splitting up large blocks of coal, these small wedges, measuring twelve to eighteen inches and weighing from two to four pounds, are indispensable to the collier in most seams. Where explosives are entirely prohibited and the coal is extremely hard, as in some of the South Wales mines, the collier is obliged to get his coal down by means of these handy instruments. After holing a few inches, the miner inserts his wedge so as to break off the coal to the nearest *shut* or *break*, and in this way brings the coal down. In getting down hard roof and in metal work, wedges are extremely useful to the man who knows how to use them to the best advantage.

Stub and Feather.—This consists of a steel *stub* or wedge driven in between two tapered liners of steel called *feathers*, which have their thin end near the front of the hole.

Multiple Wedge (Fig. 61).—This is simply an improved form of the stub and feather. After the liners have been

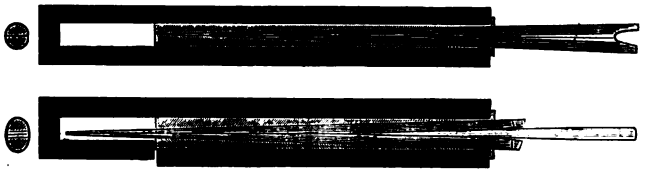


FIG. 61.—Multiple Wedge.

placed in the hole, a pair of feathers are inserted and driven up as far as possible, after which a second or a third feather may be used until the coal is broken down.

The Hydraulic Mining Cartridge.—This machine differs from all other mechanical substitutes for blasting. It is not worked

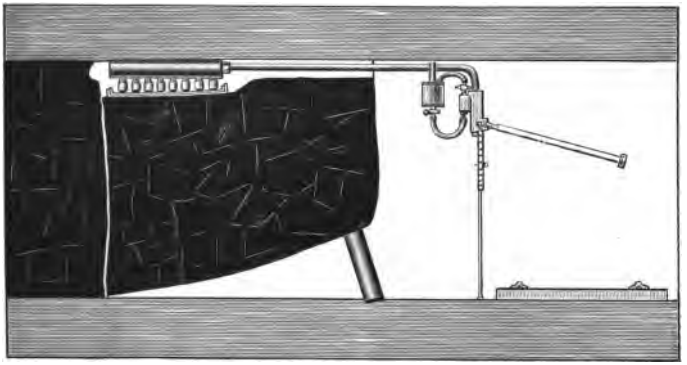


FIG. 62.—Hydraulic Mining Cartridge.

upon the principle of the wedge, and consequently the power expended in forcing a wedge into the hole is saved. It is simply an arrangement of pistons (Fig. 62), which after being placed in the hole are driven out by means of a hand pump, thus exerting considerable pressure upon the coal. The pressure required to break down the coal varies of course with different seams. The total area of the pistons is 20 sq. inches, therefore a pressure of one ton to the square inch on the

pump ram produces a pressure of twenty tons on the coal. This is sufficient for some seams, while three tons to the square inch, or sixty tons on the coal, may be required for others. The length of the cartridge is 18 inches. A hole $3\frac{1}{4}$ inches diameter is required to be drilled, and the pistons travel a distance of $2\frac{1}{2}$ inches. The pump is attached to the end of the tube projecting from the hole (Fig. 62), and is so arranged that the water used runs back into the pump after each operation. Having few parts, and being simple and strong in construction, it is possible, with the mining cartridge, to obtain enormous pressure without risk of damage to the machine. This appliance has been in continual use at some pits for several years. The great advantages of a mechanical substitute for explosives of this kind are as follows:

1. There is no danger of igniting gas or coal dust.
2. The dangers of charging and firing are avoided.
3. A greater percentage of hard, unshattered, round coal is produced.
4. The roof is uninjured after the operation.
5. There is no interference with the working of the mine, as it is possible to use the machine while the collier is at work.

Questions on Chapter VI.

1. Describe the general character and structure of a coal seam and its associated strata. (1895.)

2. What kind of bedded rocks make up the Coal Measures? State what you know regarding their nature and which of them will generally make a good roof or floor. (1902.)

3. Describe and sketch the following tools: pick, shovel, hammer, hand drill.

4. Describe a good hand machine drill for boring holes in coal.

5. What is an explosive, and what are the qualifications necessary in a good mining explosive?

6. Describe the process of charging and stemming a bore hole and firing the shot by electricity.

7. Give some rules for ensuring safety in blasting or shot-firing as far as possible. (1901.)

8. Describe some methods that have been adopted for breaking down coal and rock without explosives. (1898.)

9. Explain the chief causes of blown-out shots, and how you would guard against them.

10. How is an electrical detonator connected to the charge in the shot hole on the one hand, and to the wires leading to an electrical machine on the other? How are the wires in the shot hole protected from injury while the hole is being tamped? Draw a section of a detonator, either high or low tension, and state which it is. (1900.)

CHAPTER VII.

MODES OF WORKING.

Setting out the Pit Bottom.—As more room is needed at the bottom of the shaft and in its neighbourhood than is required higher up the shaft, it is necessary to determine, before sinking is finished, the form and size of the shaft at the bottom. Three different plans have been adopted for enlarging.

First Method.—The shaft is continued to the bottom without any widening, and a road is afterwards driven round the shaft on each side to provide the necessary room and to get tubs from one side of the pit to the other without persons crossing the shaft and being liable to be caught by falling material.

Second Method.—The shaft is widened by what is known as **Bell-mouthing.** When within a given distance of the bottom, the additional width having been decided upon, the sides, instead of being sunk vertically as before, are opened out gradually and in exact proportion to the depth and width required. Assuming, for example, that the shaft is 12 feet diameter, and that it is to be widened to 18 feet, the widening in this case may be begun when the sinking gets within 18 yards of the bottom. In this case the sides all round will deviate from the vertical at the rate of 2 inches for each yard in depth. The point to be noted is that the angle where widening begins should not be too great.

Third Method.—This plan is known as the **Saddle Arch.** This is formed by springing an arch on each side of the shaft without a pillar between, the arch being sprung at the height where the roof of the finished road on each side will be.

The shaft being finished, arrangements are made on each side so that there can be a constant supply of full tubs to,

and of empty tubs from, the cages; also that changes can be effected readily, either by passing tubs from one line of rails to another, or from one side of the shaft to the other. Where a large quantity of coal per day is sent up the shaft, great skill is sometimes required in order to secure this. Many plans have been adopted.

In some mines the waggon roads on the two sides of the shaft are on the same level, and, except for special reasons, as the full tub is pushed into the cage on one side, the empty is pulled out at the other. In this arrangement there is generally a line of rails for the full tubs opposite each cage at each side of the pit, and a line for the empties in the middle, with points and crossings so arranged that tubs can be passed readily from one line of rails to the other in the event of there being more coal on one side than is required.

Another plan is to have one side of the pit at one elevation, so that the lower deck can be loaded, and the other side at a higher elevation opposite the upper deck. This, of course, necessitates similar arrangements at the pit top; but where there are only two decks, it saves the engineman the labour and time of moving the cage twice.

The above arrangements are more particularly applicable to the cases where the levels start directly from the shaft on each side, and where the engine house stands directly over one of the levels.

In some cases the engine house is situated on the higher side of the shaft, and the full tubs are brought along levels to the higher side and run thence a few yards down hill to the cage, pushing the empties out as they go in. In such cases all the tubs of coal go in at one side of the cages, and the "empties" go out at the other. This method also is found to be very convenient and expeditious.

Shaft Pillars.—A certain area of coal in the vicinity of the shaft is left unworked in order to serve as a support for the shaft and for the buildings and other important erections at the surface. The extent of this solid pillar of coal will be determined by certain conditions, viz., the depth of the seam from the surface, the inclination and thickness of the coal, and the strength and character of the coal and roof. In flat seams it may be assumed that the line of breakage is at right angles to the line of stratification. It will therefore be an easy matter

to allow a pillar to remain of sufficient size to protect the various buildings on the surface, allowing an extra area in case of a deep shaft or a thick seam.

Where the strata are highly inclined, it will be understood that the line of breakage is not a line at right angles to the surface nor yet at right angles to the stratification. It will certainly be necessary to leave a sufficient width on the higher side to prevent the line of breakage occurring in such a position as to cross the shaft, or even to approach the erections on the higher side; consequently, a fairly large width will have to be left on that side in the case of highly inclined seams, and this will be increased according to the thickness of the seam. On the lower side, the opposite effect is produced, and so the pillar may be much narrower on that side.

There is a great difficulty in fixing a rule to obtain the size of the shaft pillar, as it will depend, as already said, upon the circumstances existing at any particular mine. In flat seams of less than 5 or 6 feet in thickness, the ordinary subsidence may extend on all sides to a distance equal to $\frac{1}{8}$ or $\frac{1}{10}$ of the depth; but to this is generally added an extra $\frac{1}{20}$ of the depth, or even as much as $\frac{1}{10}$, thus doubling the protected area. When the seams are inclined, and, provided the nature of the strata is the same, the area of coal left to protect the surface is not necessarily increased, but it will have to be arranged so as to allow of a greater width of unworked coal on the "higher" or "rise" side. It will probably be safest to allow on this side a line of breakage which occurs at right angles to the seam and clears all important buildings on the surface. At any rate, this line should include an area not less than that obtained by striking a line midway between the line at right angles to the seam and a line drawn perpendicularly from the limit of the surface erections; on the dip side it will be right to allow $\frac{1}{10}$ of the depth of the seam added to the midway line thus obtained.

The **direction of the main haulage roads** will be determined by the dip of the mine, the shape and extent of the area of the coal to be worked, and the relative positions of the two shafts. The levels are driven in the coal; consequently they are in the direction of the strike (p. 92) and at right angles to the dip (p. 92). A slight rise, however, is allowed, constituting **water level**—a term used by miners to denote that the road rises

sufficiently to allow of the flow of water to the shaft. It is also necessary to provide for a small rise in the road in order to facilitate the hauling of the full tubs towards the shaft. M. André considers that an incline of 1 in 130, or a little more than ¼ inch to the yard, gives the maximum of advantageous effect to horse-power in drawing the full tubs towards and the empty tubs away from the shaft. This amount will have to be reduced slightly in the case of long levels.

The **size of the main road pillars**, where it is thought necessary to leave them, and happily this is becoming less frequent, will depend upon the system of working the coal, the thickness of the seam and the conditions at the surface. The pillars are always rectangular, their sides being parallel to the strike and dip; the longest side is generally in the direction of the level. The side is sometimes as long as 200 feet, as when three levels are driven parallel to each other, and then the pillar serves as a panel to cut off one area of working from the haulage roads and prevents the spread of creep or subsidence, gob fires, etc. In other cases, roads are driven through the pillars at intervals of 10, 20, 50 or 100 yards. The width of the pillars also varies. Where they serve as panels they may be 80 or 100 feet wide; but for ordinary purposes they are much less, 30 or 50 feet pillars in the case of pillar and stall working (p. 119) being a convenient size; while in the case of roadside pillars, left to support the roof of the road in longwall working (p. 121), 10, 12 or 15 feet is sufficient. It will not be out of place to repeat here that the leaving of pillars for this purpose has many disadvantages, and it is most probable that the tendency in future will be to endeavour to take out the whole of the coal and leave artificial supports in the shape of pack walls, or complete stowing, which will allow of the more uniform settling of the roof and prove of less cost in the maintenance of the roads.

The **crushing of the pillars**, where it is necessary to leave them, and especially in deep mines, is an important feature. It is possible that in seams of 600 yards in depth the pillars left will become crushed. To ensure the non-crushing of pillars at smaller depths, the following proportion, fixed by Mr. Jos. Dickinson, late H.M.I.M., should prove sufficient:

For depths of about 150 yards, ¼ to be left in pillars.

„	„	300	„	½	„	„
„	„	450	„	⅔	„	„

Methods of Working.—Seams of coal vary so widely in character, in thickness, in the degree of hardness, in inclination, roof, floor, fractures, faces, cleats and various other particulars, that it is impossible to determine how a seam may be worked to the greatest advantage until these points have been carefully noted and considered. Even the same mine, or seam, may vary so much in some of the points named, within a comparatively limited area, as to necessitate working in different ways in the same pit or colliery. Hence it follows that no one method has ever been fixed upon for all mines. It would be next to impossible to describe the many different ways in which mines have been worked, but it would probably be correct to say that all are modifications or combinations of two main systems, the **Pillar and Stall** and the **Longwall.**

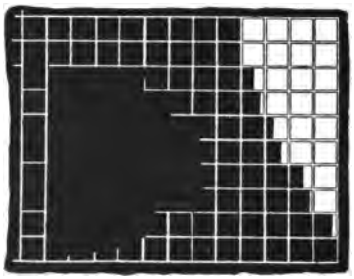


FIG. 63.—Pillar and Stall Method.

Pillar and Stall.—By this system is meant that method of working by which the coal seam to be worked is divided or cut into a series of separate blocks, panels or pillars, as they are most frequently termed, by pairs of narrow tram roads (Fig. 63).

Starting from the winding shaft, one of these pairs will be driven along the line of level of the coal each way from the shaft, that is, assuming the dip of the seam to be from north to south, one of these pairs will be driven eastward and the other westward, and, as there must be a constant current of air going past the men, a connection is made at short distances between the two roads to form a short circuit. Until this connection has been made the air has to go along one side of the road and return along the other (Fig. 64), the road being divided by sheets hanging along the middle, or by air-pipes, or other plans to be considered more fully when treating of ventilation. It is sufficient at this stage to say that all such divisions of roads are objectionable and sources of danger, and should only be adopted to a very limited extent and where absolutely

necessary. The distances between the two roads of a pair of levels and the distances between their connections will be governed by

(*a*) the amount of firedamp given off;
(*b*) the character of the seam;
(*c*) the inclination; and
(*d*) the nature of roof,

and other conditions, and must be decided in each case according to the conditions there existing.

These pairs of levels have sometimes a third level running parallel with them and having similar connections. In this

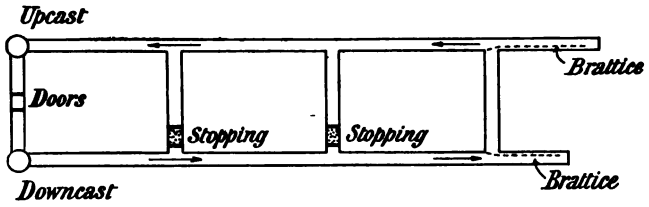


FIG. 64.—Method of Ventilation during Opening-out of Mine.

case, the middle level will form the main drawing or haulage road, along which the coal is brought, whilst the level on the lower side forms the waterway and the one on the higher side the airway. In such circumstances the waterway cannot be relied upon as an airway. Besides these two pairs of levels, which we have supposed to be going east and west, pairs of brows will be started out of these at intervals of perhaps 100 to 150 yards, and will be driven at right angles to the levels, except where the inclination of the seam is too steep, in which case the brows will be driven at such an angle as may be deemed advisable with a view to future haulage. When the brows have been driven a certain distance, previously determined by existing conditions and probably varying from 50 to 150 yards, pairs of levels will be started out of them similar to those first named. These levels and brows are continually extended and other levels and brows started, as often as the requisite length has been driven, until the whole field of coal to be got has been cut up into rectangular blocks, measuring it may be from 100 to 150 yards one way and 50 to 100, or some-

times as much as 150, the other way. Its general appearance on the working plan when thus drawn might remind one of a town having long streets reaching from boundary to boundary in one direction, and these crossed by other streets at right angles to them. In this case the streets and back streets would be in reality the parallel and cross roads, and the blocks of buildings the pillars of solid coal.

Getting Pillars.—As it is very costly to drive all this narrow work or **strait** work, as it is sometimes called, the cost in some cases exceeding the price at which the coal will sell, it frequently happens that long before the boundary is reached certain of these pillars are selected for being worked out at once in order both to get more coal and also to get it cheaper. In such cases, especially in fiery mines, great care has to be exercised in order that the spaces from which the coal has been taken may not become gasometers or reservoirs of gas. In this connection it may be noted that no dirt should be sent out of a mine until every place not intended to be used has been filled as full as possible. This plan is at once a safeguard against accumulations of gas and an assistance to the roof, and helps to give a feeling of greater security to all engaged in the mine.

Longwall Working.—By this term is meant the method of taking out the whole of the coal, after getting a little distance from the shaft, without first driving narrow roads.

The pillar of coal, known as the **shaft pillar**, is left on each side to support the shaft and all the buildings on the surface within a given distance, and upon reaching that point the workings are opened out in every direction necessary to get room for the required number of men to be working along lines or faces of coal in such positions as will yield the best coal at the cheapest rate.

Of course the best coal in this case means the coal with the greatest proportion of *round*, or big coal, in it. It is well known that every mine has to be worked in a certain way peculiar to itself if it is to yield the greatest quantity of round coal. And it is also well known that if a mine is to be worked in the most economical manner, every condition of the mine must be taken into account. Hence, all the faces will be driven and all the drawing and ventilating roads formed in accordance with the requirements of each particular

mine. Herein is found room and opportunity for the exercise of the highest talents of the mining engineer and manager. No general rule or law can be laid down as to the direction or size of roads, nor as to distance between, so far as dimensions or distances go, but the points previously referred to must be observed. If the roads are intended for airways they should be as large as practicable, so that ventilation may be better, easier and less costly; but a bad roof will affect the width, and a thin seam with a hard roof or floor, or both, will affect the cost. Of course, in almost every mine, a certain proportion of the coal will be above the level of the shaft bottom and a certain proportion below. If the mine be in the least wet, both areas will need to be cut out with due regard to the necessity of getting the water from the working places to the shaft as freely and uninterruptedly as possible, so that it shall not interfere with the men's working. For this purpose, waterways rising not less than 1 in 200, and as much more as other requirements allow, must be started from the bottom of the shaft at a sufficient distance below the landings from the cages, so that these never get as low as the water.

The direction of dip and strike of the seam, and the allowance of a rise of from 1 in 130 to 1 in 200, will give the direction of what are known as the **pit levels** (Fig. 65), from which the direction of all other so-called levels can be calculated.

When a mine does not dip at a greater rate than about 1 in 7, other main roads are driven at right angles to these, and generally a third set of roads at an angle of about 45° to the first road. But the third set of roads, called **slants**, and their direction, is dependent upon and regulated by the dip of the mine, the figure of the estate and the necessity or otherwise for increasing the number of roads or shortening the haulage distances in existing roads.

Fig. 65 is an example of Longwall working well adapted to a thin seam, with an easy inclination, from 1 in 6 to 1 in 10. Two levels are driven East and West from the winding shaft, the rise and dip of the seam being in this case North and South. A pillar of coal 150 yards thick on the East, 150 on the West, and 200 on the North side is left for the support of the shaft and buildings on the surface, and beyond this pillar the whole of the coal is taken out. At distances of

about 100 yards from each other, levels are driven from a pair of brows running in a northerly direction. On the lower side of the pit a **downbrow**, that is a road driven directly on the dip of the seam, is driven a short distance, and other levels are driven each way, the coal on the higher side only being got to commence with. To lessen the distance over which the coal must be hauled by the drawers, and also to avoid long lengths of drawing roads, requiring to be maintained, two slants are driven from a point near the shaft, one in a north-easterly and the other in a north-westerly direction. As the two first-named pairs of levels are extended, other slants

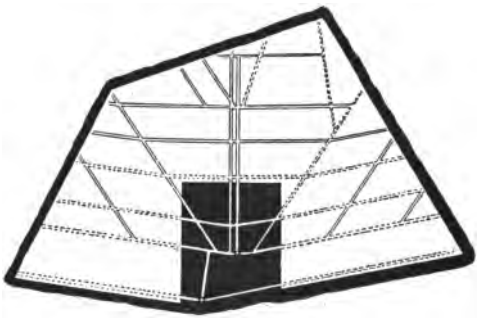


FIG. 65.—Longwall Method.

are started about every 200 yards; and down these slants the coal is brought to the main levels, whilst the distances are short, by the drawer, but afterwards by machinery, the slants being used as self-acting inclines, or **jig-brows** as they are termed.

In working a seam of coal it is almost invariably found that working on the end which is at right angles to the face is more difficult than working on the face, but it produces a larger proportion of **round**, or best coal. A slightly higher rate of wages is generally paid for working on end, but this is of course covered by the better price obtained for the coal. There are many other circumstances, such as the best direction for keeping good roads, which must be taken into account in deciding what directions the coal shall be worked in, face, end, or half-end and face, that is, midway

between end and face direction. In the case before us. the lines along which the workings are advancing, though in three different directions, are all nearly half-end and face (p. 92).

Advantages and Disadvantages of the Two Systems.—Assuming all the conditions to be favourable to the working of Longwall, we may put its advantages over Pillar and Stall as follows:

1. Less coal lost in the working, there being no crushed pillars.
2. The coal is of a better quality, realising a higher price.
3. The cost of getting is less owing to very little side cutting.
4. Ventilation is easier, and therefore safer and less costly.

There are, of course, certain conditions more or less unfavourable to Longwall work, and under these conditions the Pillar and Stall System may commend itself, the advantages outweighing the disadvantages, as in the following cases:

1. Where the coalfield has been greatly disturbed by faults, continuous wide faces in one straight line cannot well be maintained.
2. Where there are many important structures, public buildings, railways, waterways, reservoirs, etc., it is scarcely possible to get coal under these by the Longwall method without some slight disturbance.
3. Where the seam is thick and the roof is hard, there is a difficulty in obtaining packing material. In such circumstances some engineers are willing to pay a moderately good sum for debris of any suitable nature to be sent from the surface to fill the spaces left by the removal of the coal.

Highly Inclined Seams.—In very steep seams, special methods of working the coal are generally necessary. The difficulty of undercutting and filling the coal in safety is not the greatest drawback in steep seams; but the extra labour in hauling the coal and the need for greater care in the supporting of the roads and faces make the working of very steep seams a serious consideration. It is not right to assume that it will only be necessary to place the shafts at the lower side to enable the whole of the coal to be jigged down to convenient

levels and thus brought easily to the shaft. The dangers and inconveniences of self-acting inclines increase with the steeper gradients, and many managers prefer in some cases to work the coal on the deep (Fig. 66, *B*, *B*) by means of downbrows and levels. The faces can either be worked towards the rise *A*, *A* or level course *B*, *B* as the case may be. In steep seams, the question of filling the **goafs**, or empty spaces left owing to

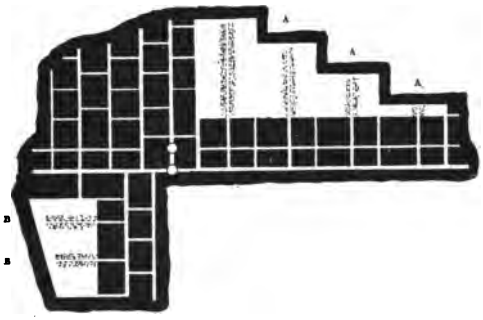


FIG. 66.—Modification of Longwall and Pillar and Stall, suitable for highly inclined Seam, or Seam with a Bad Roof.

the removal of the coal, is important. It is generally necessary to stow these with debris got from drifts or roadways and augmented if need be by rubbish brought from the surface. In fiery mines especially, this complete stowing of worked-out spaces is imperative.

Questions on Chapter VII.

1. Describe the various forms of construction of the pit bottom.

2. Describe and sketch a good method of setting out the pit bottom for dealing with 1,000 tons per day.

3. What are shaft pillars? Give a rule for determining their size.

4. What considerations determine the size and direction of the main roads underground?

5. Describe briefly the principal methods of working coal practised in the United Kingdom. (1897.)

6. Describe carefully the Longwall method of working.

7. Show how the roadways in a Longwall working are prevented from exceeding a certain predetermined length, that is to say, how they are cut off when they attain that length. (1900.)

8. Discuss fully the method of working a bed of coal, ironstone or other mineral by the Pillar and Stall system. (1903.)

9. Draw the working face of a colliery with which you are acquainted, showing the manner of "getting" the coal and supporting the roof. (1901.)

10. What are the advantages and disadvantages of the Longwall and Pillar and Stall methods of working?

CHAPTER VIII.

TIMBERING.

THE important question of how best to support the roof and sides of the roads, and the roof and coal at the face, is one which is of great interest to the mining student. Almost 50 per cent. of the deaths from falls may be attributed to the failure to carry out these operations in the best possible manner.

Timber.—Different Kinds: Their Use, Quality and Strength.—The chief timbers used in mines are those called **soft woods**, although a few **hard woods** are used for special work.

The soft-woods include *fir*, *pine* and *larch*. The special characteristics of these soft-wood trees are straightness, regularity, lightness and cheapness. They are straight-fibred, long-grained timbers, and will resist pressure from above, that is in the direction of their fibres, better than the close-grained hard woods, which are most useful where pressure may be exerted across the fibres. The strength along the grain of timber is greatest in those woods which have the straightest and most distinct fibres.

Use and Quality.—Timber for **props** or **sprags** should be capable of resisting pressure from above, should bend considerably without breaking and should not be greatly affected by change of atmosphere or by damp workings. Timber for **bars** should withstand strain across the fibres, and should bend considerably before breaking. The most useful timbers for both these purposes are certainly fir and larch, and are largely used.

Although not so cheap and light as fir and larch, pitch pine is a most useful mining timber. It is suitable both for bars and bar legs on haulage roads, being much more durable than larch or fir. Having a fair amount of pitch in it, it is not so easily affected by the atmosphere. It is straight, square and not liable to warp or twist.

Mining timbers are therefore subject to stress in three directions :

1. Transverse strain across the fibres.

2. Compression along, or parallel to the fibres, tending to shorten.

3. Crushing strain, or strain tending to elongate.

Ordinary bars set on legs or on the sides, and supporting a roof in the middle, are examples of the first kind. Props, sprags and bar legs are examples of the second ; and split bars commonly used at the face, supported by two legs, which wedge the bar firmly against the roof, are examples of the third kind.

Strength of Pit Props and Bars.—The strength of props and bars varies not only in different timbers, but is affected by the condition of the timber at the time of its employment. The age, time and conditions of growth, freedom from knots or bends all influence the strength of timbers. Again, the seasoning of a prop not only lengthens its life, but as a rule increases its strength.

In experimenting with props in regard to their strength, the author found that a pitch pine prop 3 ft. long sustained a weight, when set vertically, of 21 tons, at which point it broke. This breaking point is 25 per cent. higher than the weight given by one authority in the rule for strength of props. Tests made upon a Norway bar, 6 in. square and 6 ft. 6 in. between supports, with ends remaining loose, showed that it broke with a pressure of 3 tons. With both ends fixed and wedged against the roof, a pressure of 5 tons was required to break it. These were not equal to the strengths given in the rules, and as so much depends upon the condition and quality of the timber, a large margin of safety should be allowed.

Taking four mining timbers from the *Practical Engineer*, we find as follows :

Timber.	Specific Gravity.	Breaking Weight Beam 12 ins. long, 1 sq. in., supported at ends, loaded in middle.	Crushing Stress per sq. inch.	Tenacity per sq. inch.
		lbs.	lbs.	lbs.
English Oak, -	0·93	650	8,250	15,000
Pitch Pine, - -	0·70	550	6,000	12,000
Fir, Larch, - -	0·53	550	5,500	11,000
Fir, Riga, - -	0·53	525	5,300	12,500

From this table we see that oak is the heaviest and strongest in every direction of strain. It is also the most durable, but as it is expensive it is used only for special work. The larch and Riga fir are equal in density and about the lightest of timbers. Larch has a higher breaking and crushing strain, which makes it a better timber than fir for the strains that are likely to come upon bars and bar legs; but fir is much stronger in tenacity, and is consequently a superior timber for bars on the working face.

Herr Dutting, at König Colliery, Neunkirchan, has made tests with actual pit props, and the following are some of the conclusions arrived at:

Beech, fir, pine and oak were tested. The lengths of the props varied from 39 to 99 inches, with an average diameter of 5 inches, and an average area of 20 square inches. The breakage weight of these woods when dried and set vertically, averaged in lbs. per square inch of area: beech 3,627; fir 3,385; pine 2,958; oak 2,958. Most of the props broke by flexure, that is, bending; fir gave most warning, then pine; beech and oak gave least notice. For durability in return airways, pine showed best, then fir; beech and oak were poor.

From the foregoing figures giving the results of tests, the student is able to form some idea of the relative strengths of timbers; but, as before mentioned, it is quite necessary to take into account the condition of the timber at the time of its employment. It should also be remembered that the weight which woods will bear without being permanently altered cannot be more than 70 per cent. of the crushing weight, and in most instances is as low as 50 per cent., this depending upon the character of the timber and the conditions under which it is used.

Some authorities contend that the strength of a prop set vertically is independent of its length, provided the length of the prop is not greater than 30 times its diameter. Other authorities take a lower limit, contending that 10 or 15 times the diameter is a sufficient margin. However this may be, it is quite reasonable to assume that a long prop being more liable to be set out of the perpendicular than a short one, is consequently more likely to give way to the pressure of the roof. That is to say, a prop 5 inches diameter and 3 feet long would be more easily set in the right position than a prop 5 inches diameter and 6 feet long. And as the prop which is

set most directly in the line of pressure will not easily break, it follows that the shorter prop in these circumstances will be strongest.

Stocking Timber.—In order to keep the large quantities of timber in good condition and preservation before using, large covered buildings should be used for storing, and means of ventilation provided. As a rule the timber is supplied with the bark still on; many owners, however, prefer stripped timber, and contend that this is necessary in order to ensure longer life. The larger pieces should be stacked horizontally, the small ones fixed on end.

The butt-end should always be placed downwards in stacking, and the butt left exposed to the air.

To obtain the best results, only timber felled during the preceding winter should be stacked, and the following timbers should be carefully excluded:

1. Timber in a bad state of preservation on arrival.
2. Crooked poles unfit for cutting up into props.
3. Crooked props (some proprietors allow a deviation from the vertical of only 1½ inches to the yard).
4. Props cut from branches of trees or from tops of trees which have had their branches cut off.

Non-resinous timbers with a rough bark are often smoothed as much as possible, so that half at least of the bark is stripped. Resinous timbers, which are naturally smoother, have the bark completely removed in some collieries.

Seasoning Timber.—Before being used, most mining timbers are seasoned and creosoted, and this is a distinct advantage.

In **seasoning**, the timbers are placed in a desiccating or drying chamber, and the moisture driven off. This chamber is heated to a temperature of 100° to 120° F., and 1 cubic foot of air to every 3 cubic feet capacity of chamber driven in each minute.

Creosote is an antiseptic or preservative obtained by distillation from wood or coal. It has the remarkable power of preventing the decay of timbers. Railway sleepers and mining timbers, which are liable to be frequently wetted, are first saturated with creosote, and in this way preserved for almost indefinite periods. To do this, the timbers, after having all moisture and sap dried out, are placed in boilers, and the creosote driven into the pores of the wood under pressure.

Salting props, by soaking them in a solution of common salt and water for several days, is sometimes adopted, but is not so satisfactory as creosoting.

Preservation of Timber by Electricity.—There is little doubt that timber can be efficiently creosoted or salted by means of electricity, which has the power of modifying the condition of woods and other materials which is not possessed by any other power. When creosote is forced into the timber under pressure, it cannot be said to be perfectly done; there is generally a portion of the interior left untouched. By electricity, the creosote or salt can be carried easily to the interior, and the timber impregnated throughout. This property which electricity possesses of causing liquids or salts, which are good conductors, to pass through porous substances is certainly of great value as a means of seasoning and preserving mining timbers.

Experiments show that fully creosoted and partly seasoned props are not as a rule as strong as those lightly creosoted and fully seasoned.

In these various ways dry rot in timbers is prevented, the length of life of props and bars considerably lengthened, and the timber may be used in damp or dry mines or in main return airways without the same risk of deterioration as would be the case with unseasoned timbers.

Timbering.—Theory of Pressure.—The theory of the amount and direction of the pressure of the strata upon the timber set to withstand it must form an important part of the subject of timbering. It is quite certain that the amount of pressure is not equal to the weight of the whole of the strata occurring between the seam and the surface. No timbers would be strong enough to bear such a strain. Each bed or stratum, being more or less horizontal and continuous, receives side or lateral support, just as a pile of planks stretched over a space of some yards may bend slightly, but does not break owing to the fibres of the timbers being continuous, and because the planks pass on each side to solid supports. For this reason it may be said that a hard solid roof is a strong roof, while a roof containing breaks and slips, and consequently having little side support, may be called a bad or weak roof. And as a mine at a great depth may have a good hard roof, and a shallow mine may have a bad roof, it will be seen that the strength of the roof does not altogether depend upon the depth from the surface. The chief factors

influencing the amount of timber required to support the roof may be stated as follows :

1. The nature of the roof and floor.
2. The method of working.
3. The depth from the surface.
4. The thickness and inclination of the seam.

As a rule, clod and metal roofs require most timber, the carbonaceous or coal roof requiring less, and the arenaceous or rock roof least. There are many exceptions to this rule, however, so that it is necessary to observe carefully and constantly the nature of the roof. Again, some roofs are greatly affected by the action of the air upon them after being exposed to it for a short time, and although apparently hard and solid for a time, are liable to disintegrate or break up and become unsafe.

The method of working the mine, and the number and size of the pillars of coal left, will affect the amount of timber required. In thick seams it may be necessary to leave pillars of coal to support the roof, but as the longwall or widework method of getting coal is becoming more generally adopted, new means of timbering the roads and faces are being used. Many mines are now being worked on the longwall method (p. 121), which formerly were considered too thick to allow of an unbroken face of any length, and other mines possessing roofs considered bad have been found safe and economical to work with a modified system of longwall and a good arrangement of pack walls and timbering. It is quite common, in mines of only moderate thickness, for there to be a recognised length of bay or face beyond which it is considered unwise to go. A **fast side**, *i.e.* a face or roadway cutting having a side of solid coal and the other open to the goaf, must then be cut, and a pillar left to be brought forward at a later stage, because it is thought the roof will only stand this width safely or economically. If, in many of these cases, a little more confidence was placed in the roof, and the money spent in cutting along the fast side, and the money lost in the decreased value of small coal, was spent in extra timber and in maintaining the roads, then it is probable that the roof would quickly become less dangerous and working would be more economical. It is the practice in some collieries to drive out straight roads to the boundary, and to bring the coal back

to the pit shaft. In such cases the pillars of coal form natural and justifiable supports.

As already mentioned, the depth of seam from the surface does not affect the number and position of supports to the same extent as the nature of the roof and floor and the method of working. Where, however, a highly inclined seam of coal is being worked, it is possible that the workings at the lower side of the pit will require more timber than the higher side workings; but as it is often found in mines of this sort that the roof is of uniform strength throughout the higher and lower workings, it may be said that the depth from the surface does not greatly affect the strength of the roof. The thickness and inclination of the seam affect the timbering chiefly in respect to the direction of the pressure.

Direction of Pressure.—Although it may be admitted that the strength of a prop is not greatly influenced by its length

FIG. 67.—Position of Prop in Horizontal Seams.

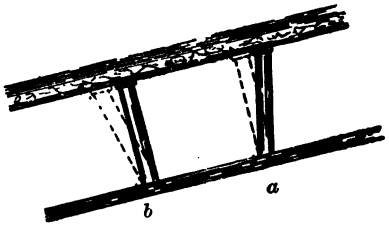


FIG. 68.—Position of Props in Inclined Seams.

within certain limits, yet there is a greater risk of a long prop being bent or broken by flexure than a short one. In other words, it is more difficult to set a long prop correctly than a short one. If the seam is highly inclined, the work of fixing the prop in such a position that it will be tightened by the weighting of the roof, instead of pushed out, is increased. In horizontal mines the weight as a rule comes on at right angles to the bedding, consequently the correct position for a prop to resist this pressure will be vertical (Fig. 67). Even where mines are inclined, it is probable that the main pressure of the strata is in a direction at right angles to the bedding. In order to guard against side-thrust, however, and the tendency of the weight to ride to the lower side, props should be set with a

slight inclination at the top towards the higher side. When the weight comes on, therefore, the side-thrust or riding of the roof will cause the prop to be forced gradually to a more tightened position (Fig. 68, *a*), vertical to the bedding, instead of forcing it out altogether (Fig. 68, *b*).

Different authorities have endeavoured to fix a maximum and minimum slope for props under these conditions. Mr. Sawyer recommends a maximum slope of one-sixth of the dip, or a minimum of one-third of the one-sixth. Other authorities allow an inclination of half-an-inch per foot of length of prop, but in any case the inclination will be regulated by the length and diameter of the prop, as it is necessary that the line of pressure at the top should not fall outside the base of the prop.

Modes of Timbering Roads and Working Places.—The different modes of timbering roads and faces are as follows:

1. Single Props.
2. Prop and Lid.
3. Props and Bars.
4. Cogs and Chocks.
5. Cocker Megs and Cocker Sprags.
6. Holing Props or Sprags.

The whole of these timbers are used in the working places, either for supporting the roof or the coal face. They are used, set vertically in the form of props, for resisting the pressure of the roof, and in the form of bars, set horizontally against the roof, for the same purpose.

Cogs or **chocks** consist of erections of round or square timber set crosswise, and, if necessary, filled inside with dirt. In this form they make probably the strongest and most satisfactory support for the roof, especially for gate ends, that is the point at which the drawing road starts from the face; and in the intervals between packs.

Cocker spragging consists of a horizontal timber, five or six feet long, called a **cocker meg**, placed along the face, and held in position by a sprag from the floor and a **cocker sprag** from the roof. In seams containing shuts or breaks, or in thick seams, this is a very efficient form of spragging.

Holing props or sprags are the short pieces of timber set either vertically or at an angle to support the coal; a double row of sprags is sometimes necessary where the coal is likely to break away during holing.

Timbering at the Face.—Various arrangements of props, bars,

sprags, chocks, etc., are adopted in different mines, according to the nature of the roof and floor, and the thickness and hardness of the coal seam. Although examples can be given of the manner of timbering in various mines, it is impossible to fix upon any one method suitable for all seams and all roofs. It is

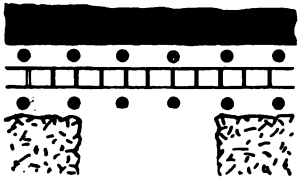


FIG. 69.—Timbering at the Face.

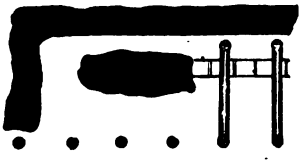


FIG. 70.—Bars set along Coal Face.

necessary that all circumstances existing at the face be taken into consideration, and even after deciding on the best method, alterations or modifications of it will be necessary in different districts of the seam. Sometimes only one or two rows of props and single sprags are required (Fig. 69). In other cases the roof is supported by props, with bars, and the coal face supported by sprags. Or again, the roof may be supported by chocks and props, and the coal by cocker spragging. Fig. 70 shows the method of timbering a **jud** (a roadway 4 to 8 yds. wide driven in a pillar of coal) or strait place by props and bars only. It also serves to illustrate the evil effect of failing to set sufficient bars, the black mass representing a fall of roof. Another method of timbering a jud is by means of chocks or cogs, and props.

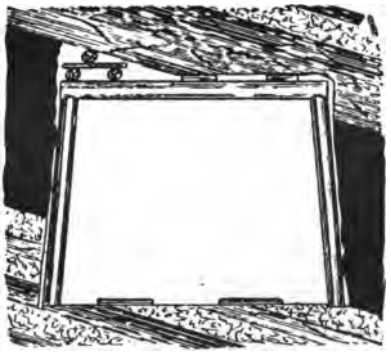


FIG. 71.—Correct Method of Packing Bars.

Bars, Lids, and Holing Sprags.—It is necessary with many roofs to set good strong bars systematically, in addition to props.

These should be carefully set, and if necessary packed on the top. The packing of bars, if done carelessly, is a great danger. They should be uniformly packed, as in Fig. 71, the weight being thus distributed over the whole length of the bar. If packed as in Fig. 72, the centre of the bar, which will stand least strain, receives the whole of the weight, and is liable to break.

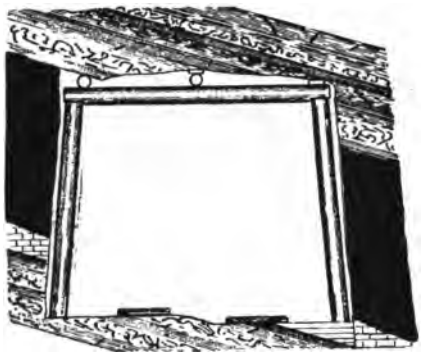


Fig. 72.—Incorrect Method of Packing Bars.

Lids are small pieces of wood placed on the top of a prop, or at the foot, to enable a larger area of the roof to be supported, and to protect the prop from splitting. If they are not fixed carefully, however, they are likely to damage the prop. They should be larger than the top of the prop, as in Fig. 73 *D*, not smaller, as in Fig. 73 *A* and *C*, as a small lid is sure to cause the prop to split immediately the weight comes on. With bad roofs the length of the lids may be extended considerably, so as to cover a greater area of roof, and fixed so as to cross at right angles any breaks that occur in the roof. They should be of hard wood, except in the case of metal roofs, where soft wooden lids placed either at the top or foot of a prop enable the pressure to come on with damage only to the lid, serving in this case the same purpose as the end of a tapered prop (p. 141).

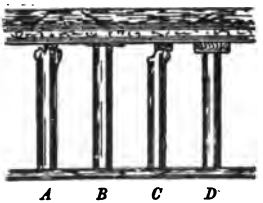


Fig. 73.—Correct and Incorrect Lids.

Sprags or **holing props** are set both with and without lids to support the coal during holing. According to General Rule 22 of the Coal Mines Regulation Act, all sprags or holing props must be set at no greater distances than six feet, but it is

necessary in many mines to set them at intervals of three or four feet. The number of sprags depends upon the nature and thickness of the coal, its freedom from partings or breaks, and the depth of the holing. In some cases it is necessary to

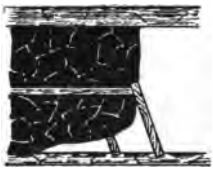


FIG. 74.—Main and Under Sprags.

A
Sprag incorrectly set.

FIG. 75.

B
Sprag correctly set.

set **under-sprags** as well as the main sprag (Fig. 74), and these should be so fixed as to have the whole area of the end of the sprag against the coal (Fig. 75 *B*), provided with a lid if the coal is friable, or cocker spragging may be adopted if a sprag and lid are insufficient. They should on no account be set as in Fig. 75 *A*, where the whole area of the end of the sprag is not in contact with the coal.

Timbering of Roadways.—Timbering of roadways differs from the timbering of the faces in two ways:

(*a*) That greater attention has to be paid to the pressure exerted on each side.

(*b*) That the supports are required to be more permanent.

As a rule roads are difficult and expensive to form and maintain, and the best method of timbering should be adopted in the first instance, so that the movement of the roof, floor and sides may do as little damage as possible.

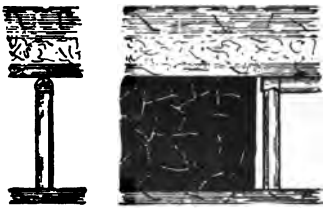


FIG. 76.—Method of Notching Bars

Bars and bar legs are chiefly employed in the timbering of roadways. To enable the leg to fit against the bar properly, and in order to prevent its being pushed out in case of side pressure, they may be notched and fitted together as in Fig. 76. If the notching, however, is badly done, the bar or the leg is liable to break. Other means adopted for

preventing the legs from being pushed out by side pressure are shown in Fig. 77. Where bad roofs or sides are to be dealt with, additional timbers have to be set; the sides and

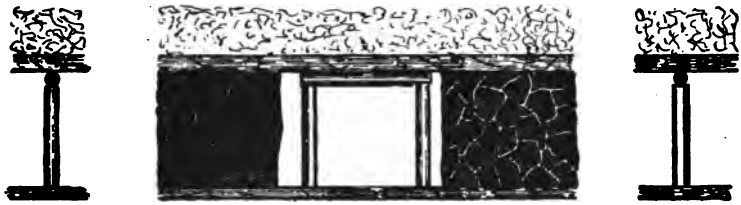


FIG. 77.—Notched Bars.

roof behind the legs and bars are lined with flat pieces of timber called **laggings, runners** or **slabs** (Fig. 78). These should fit tightly against the roof or side, and in case there are spaces behind them, these should be filled with waste dirt. As in the

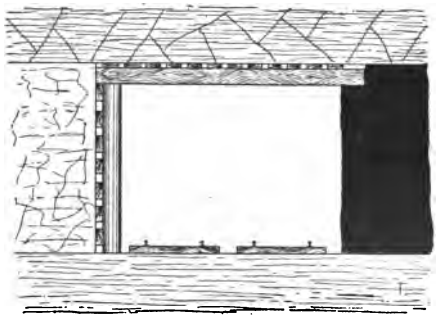


FIG. 78.—Method of Roadway Timbering showing Laggings or Runners.

case of bars at the face, roadway bars should be carefully packed, so that the greatest weight does not occur at the centre of the bar. Lids are not as a rule required or advisable between the top of the leg and the bar (Fig. 79), as they interfere with the accurate setting of the timbers, and serve no useful purpose, except in the case of extremely hard roofs, which are constantly sinking. If carefully put in, they may in

such cases be an advantage, though it is better, if possible, to place them at the foot rather than at the top of the leg.

Here again the **cocker system** of timbering can be used to advantage. Although it is a method employed more generally on the Continent than in this country, yet it is resorted to in certain cases in English mines. Its great merit is that side pressures or roof pressures only tend to tighten the supports. The megs or horizontal timbers serve not only to hold the cockers in position, but stretching for some distance along the roadway, bind the sets of timbers together. The ordinary

FIG. 79.—Methods of Setting Bars.

bars and legs are not dispensed with, the cocker timbers being simply extra strengthening supports. The ends of these cockers are carefully shaped to fit the longitudinal timbers, and as there is one of these on each side of the roadway, and a third in the centre at the top of the roadway, a large amount of fitting together is needed, and this is increased in wide roadways where two top longitudinal pieces are required. This extra shaping and fitting is the chief drawback of this effective Continental method.

A single haulage road, which, if used for travelling purposes also, would possibly be made six feet wide (Fig. 80 *A*), could, if driven, say seven feet six inches wide, be divided by means of legs or pillars into two compartments, the larger one for haulage, and the smaller one for travelling purposes (Fig. 80 *B*). In the case of a double road, such as is used for endless haulage, which, if it is to be used for travelling purposes also, would be driven, say, ten feet wide, could, if driven eleven feet wide, be divided into two compartments as in the former case (Fig. 80 *C*). There are advantages to be derived from this form of timbering, which would in many cases compensate for the extra amount of width taken, and for the slightly increased

fixed stock of timber. We may mention the following advantages :

(*a*) There would be greater safety to persons travelling.

(*b*) The smaller compartment could be utilised also for water or compressed air pipes, electric cables, and signalling apparatus.

(*c*) In some cases, notably when the road was being driven in advance of the faces, or if a tunnel was being made from one mine to another, the two compartments would form the intake and return for the air, probably saving a back tunnel.

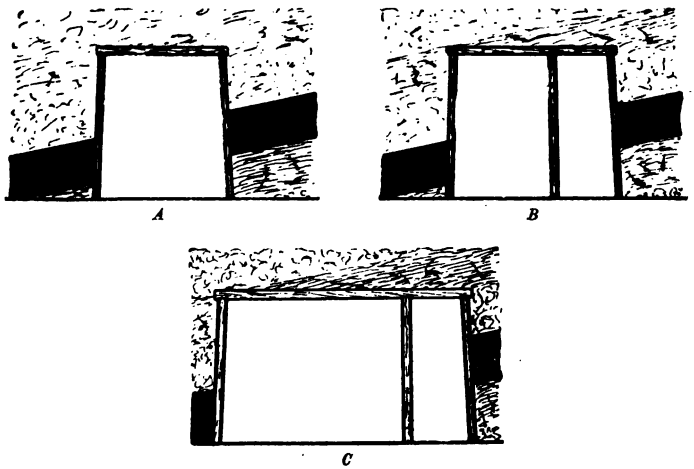


FIG. 80.—Roadway divided into Compartments.

(*d*) The bars, which as a rule are the weakest parts of the timbering, would be strengthened considerably by the shorter bearing between the posts. In the example of the two roads shown, the increased strength or efficiency of the bar would be 25 per cent. in the single road and 20 per cent. in the double road.

The Repairing of Roadways.—This is an important feature in the working of a mine. It is a necessary evil we might say, and needs good and trustworthy men to carry it out. When a bar has become broken, and requires taking out and a new one substituting, the direction of the pressure of the roof will

become changed. The adjacent timbers will have more weight to bear until the new timber is set. It is necessary therefore, that these should be strengthened, that extra props (Fig. 81) should be set temporarily under those bars, say two on each side of the fall, likely to be subject to increased weight. This is done because of the great danger to the workmen if the bars under which they are working are not adequately supported, and, because it is essential to prevent the spread of the

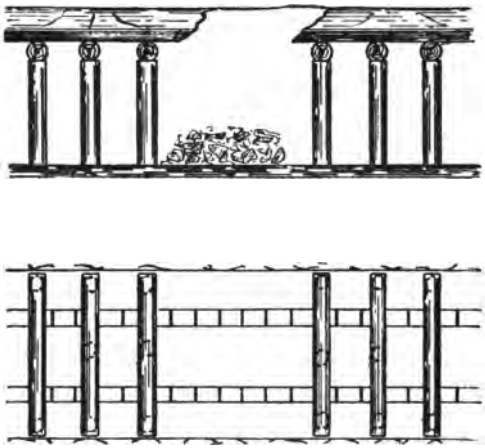


FIG. 81.—Method of repairing a Fall of Roof in a Roadway.

fall. When the new bars and legs have been set, the bar is if necessary covered with stretchers, and the space immediately above stowed with debris; the catch props may be withdrawn unless found to be holding considerable weight. In work of this sort, the idea of the chief timberman should be to secure the safety of the workman, while carefully and skilfully replacing the damaged bar without bringing undue weight upon the adjacent ones.

Tapered Pit Props and Bars.—To prevent the breakage of props under ordinary pressure of the roof, Mr. W. H. Hepplewhite has re-introduced the method of thinning or tapering one end of the prop, which allows it to yield to the sinking roof, the result being that the tapered end "burrs" or "fuzzes." This prevents

the prop from breaking until the end of the taper is reached, before which time the miner has an opportunity of removing the prop, which, if it has been properly set, and taken out at the right time, will be in no worse condition after the ten or twelve inches of "fuzzed" taper has been sawn off than when first set. This idea of making one portion of the support slightly weaker than the remaining portion, so that when the unavoidable weight comes on, the support may not be broken in the middle (under ordinary conditions the weakest part), is not entirely new. Many miners have in a less perfect manner employed the idea of chipping the bottom of the prop to enable it to "burr" under certain roofs. Some miners contend that a lid of slightly softer wood than the prop, placed at the foot, is a more satisfactory means of gaining the same end. In dealing with the subject of tapered props and bars, Mr. Hepplewhite says, "We will take a prop five feet long and six inches diameter at the thin end, and after tapering one end, use it in a pit in the ordinary course of working. Having previously ascertained that the normal depression of the roof is six inches, six feet back from the face, we calculate that the prop will require a taper eleven inches long, leaving the thin point three inches in diameter. Of course it must be understood that these props are only intended for hard, impenetrable floors, exception being taken where a few inches only of soft clunch overlies a hard floor. A prop so treated will probably sustain a dead weight of about sixteen tons before any appreciable impression is made on the tapered end. In time, the superincumbent strata over a certain area are quietly and imperceptibly settling. The smaller diameter of the tapered end of the prop will be observed to have begun to "burr" or "fuzz," and the greater the pressure the more will it advance along the taper to the ordinary thickness of the prop. When the time arrives for its withdrawal, the prop so treated will be found erect and sound, whilst an ordinary prop would have been broken in some shape or form. After the withdrawal of the prop, supposing that the burring has advanced say, four to five inches along the taper, it can be reset in the same stall on a foot-lid, and the "burring" will proceed again on the same principle."

The Maintenance of Roads and Faces.—For the maintenance of roads and faces it has become customary to rely

upon two supports, (*a*) natural, (*b*) artificial. Under the term "natural supports" we may include the coal pillars left for the purpose, and the stone or dirt packs formed from material liberated, either in getting the coal or in making the drawing roads. Under the term "artificial supports" we may include timber, iron, or steel props and bars, imported stones or dirt from the surface, bricks, etc.

With the question of coal pillars as a means of support it is not intended to deal here, except to repeat, that although it may be necessary to leave them sometimes in working thick seams, there is doubt as to their efficiency in thin seams under almost any conditions.

The Maintenance of Faces.—The chief materials for support are

(*a*) roadside packs; (*b*) middle packs;
(*c*) chocks or cogs; (*d*) loose dirt;
(*e*) props and sprags.

One or more, or all of these may be in use at one time.

The roof needs regulating as well as supporting. It is necessary to determine the means by which the roof may be gradually lowered on to some even and safe support after the coal has been taken out, and also to decide how to retain the front or face end steady while the tail or goaf end sinks down. Broadly speaking, the packs take the tail end of the weight. In thin seams, as a rule, there is sufficient elasticity in the roof to allow a gradual bend from the goaf to the face, and in that case props only are needed at the face. In the thicker seams, the unyielding timber, chocks and packs, support the face end, while the tail end settles down on the goaf packs; in such cases the roof is broken off at intervals behind the chocks—hence the importance of keeping the chocks well advanced, and the back timbers drawn. There is also an advantage in practice in building good front walls to the packs. The accompanying illustrations (Figs. 82 and 83) are inserted to show the means adopted for supporting and regulating the roof in two different mines.

1. **Packs and Single Row Chocks** (Fig. 82).—In this case there is only a single row of chocks. Each chock is moved forward a short distance at a time in a certain definite order. There are three main stages in the progression of the chocks, as

represented, say, by the first, second and third mornings, in Fig. 82 *A*, *B*, *C*.

The roads are 40 yards apart from centre to centre. There is a middle pack 3 yards wide, leaving about 14 yards between packs, partially filled by holing dirt, the drawing road packs being also 3 yards wide. The chocks are 3 yards apart, except

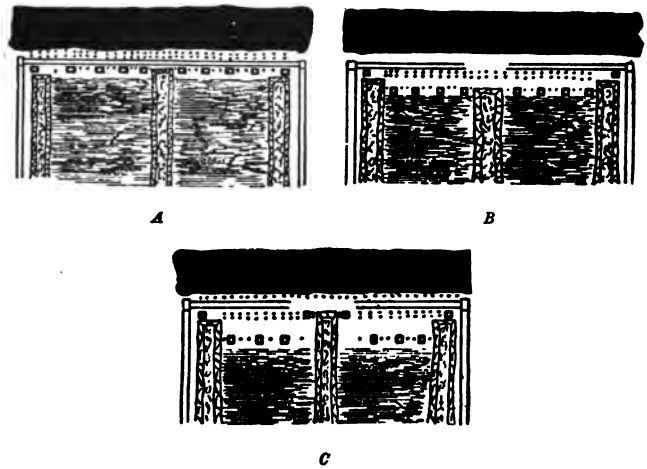


FIG. 82.—Packs and Single Row Chocks.

near the packs, where they vary a little. The props are set double, and the chocks are moved 5 feet forward after each removal. The order of procedure is as follows:

A. The "roofer-down" (that is the person appointed to make the roads in the night) at the end of the first day takes out the two roadside chocks and carries them, together with the packs, 5 feet forward; he also changes the rails along the face for the collier.

B. The "day-chocker" (that is the person appointed to maintain the roads in the daytime) then carries the middle pack and one chock on each side, 5 feet forward.

C. The next day he will carry the intermediate chocks, one by one, into line, so that in three days' time the arrangement is just as it was on the morning of the first day.

2. **Packs and Double Row of Chocks** (Fig. 83).—In this example there is a double row of chocks; the drawing roads are closer, being only 20 yards apart, and there is no middle pack. This leaves about 12 yards of waste between the packs, which are 3 yards wide as before. The chocks are 5 yards apart.

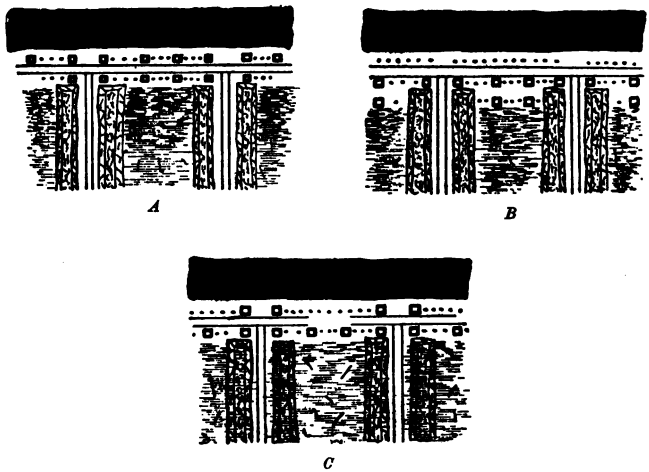


FIG. 83.—Packs and Double Row of Chocks.

There may be said to be three main stages in the progression of these chocks, as represented in Fig. 83, *A*, *B* and *C*, showing first, second and third mornings. The order of procedure is as follows:

A. The roofer-down takes out the two roadside chocks farthest from the face, and puts in a pack about 5 feet long to the other chock; he also changes the tub rails for the collier along the face.

B. The day-chocker then takes out the two goaf chocks which are farthest from the face. The roadside chock, which has been pulled out, is then set near the face, overlapping the former front chock five feet.

C. During the day the chocker brings forward the goaf chocks which he has taken out, and resets them five feet in front of the others.

On the fourth morning the position is the same as on the first morning. It is sometimes advisable, when space permits, to reset the chocks which are taken out, whether drawing roads or goaf chocks, immediately after being taken out.

On comparing the two modes of procedure, it is found that whereas each total average underground cost is about the same, the different items in the cost vary considerably; while more is paid for maintenance of faces and prop wood in No. 1 than in No. 2, there is more paid for roofing-down, and for rails and other fixed stock, in the latter case than in the former.

The Maintenance of Roads.—There is a variety of opinions as to which is the most important point to be watched in the supporting of roads. To a very great extent the roadside packs affect the condition of roads in ordinary circumstances.

The Pack and Pack Wall.—Where possible, there should be three walls to each pack—a roadside wall, a goaf wall and a front wall. This walling will then take its own particular share of roof on the effect of the weight taking place. The main roads require special care in packing. It is the custom in some collieries to take a small road, and to widen it out afterwards for haulage purposes. This is a good method, provided the pack walls are put in the full width of the intended haulage road. The second *roofing-down*, which means the taking out of a certain amount of roof in order to increase the height of the roadway, is kept a distance away from the face of the coal and just outside the limits of the "second weight." When goaf space permits, all the debris from this operation should be used for the strengthening of the roadside packs. In all cases the strongest stones should be used in the walls. As a rule, large well packed roads, although the first cost is heavy, are in the end very economical.

Systematic Timbering.—By systematic timbering is meant the plan of fixing a maximum distance at which props shall be set apart, to apply to any mine or district of a mine. By General Rule 22 of the Coal Mines Regulation Act, it is enacted that "the distance between the sprags or holing props, where they are required, shall not exceed 6 feet or such less distance as may be ordered by the Manager." In Special Rule 48 it is also specified that "every miner shall set sprags or holing props as soon as there is room, and such sprags or holing props shall be set not more than 6 feet apart." (See p. 136.)

The maximum distance for sprags, or holing props, affects all mines, but it would be impossible to fix a distance for props to apply to all mines. It is necessary, then, for the manager of a mine, after careful consideration of all the circumstances existing in any of his mines, or districts of the mines, to stipulate that the props shall be set at certain maximum distances, or oftener if necessary, and a Special Rule (Special Rule No. 1 C.M. Reg. Act, 1904) empowering the manager to determine this maximum distance is now in force at all mines.

The Courrières Method.—The number of fatal accidents from falls of ground at the Courrières Collieries, in France, has been reduced to such an extent during the last 22 years as to have attracted much attention, so much indeed that a year or two ago the Secretary of State of the Home Office instructed four of H.M. Inspectors of Mines to proceed to these collieries, and after personal inspection underground to report; their report, amongst other things, gave in substance the following valuable information:

The total thickness of all the seams is 140 feet. There are three classes of coal: bituminous, semi-bituminous and quarter-bituminous. The average thickness of the first is 3 ft. 7 in., of the second 2 ft. 10 in. and of the third 2 ft. 8 in. The roof is mostly shale, rarely sandstone. The floor is a hard underclay. The dip varies considerably, from being nearly flat to an angle of 60°, or 45°. The collieries employ 5794 persons underground, and the output is now reaching two million tons per annum. On the whole the collieries may be said to be, so far as safety goes, not particularly safe, nor yet particularly dangerous.

Method of Working the Coal.—The system adopted is a form of Longwall, but is worked in steps and not in one continuous face. Coming to the immediate question of supporting the ground, we find as follows: (*a*) Great attention is paid to the timber itself. Pine, oak, birch, ash, cherry and hornbeam are used; the last named being used green.

(*b*) Care is taken as to the supply of timber, and particularly as to the different sizes and strengths for different purposes, so that the term systematic timbering means much more than merely setting timber at given distances. The element of strength is most carefully considered.

Methods of Support.—1. **Main Roadways** are kept in excellent order by linings of masonry in some cases, in others of steel or timber, leaving little chance of any one being injured by a fall.

2. **Branch roadways** are supported systematically by frames or sets of timber placed 3 ft. 3 in. apart; each set is composed of two uprights (posts or props), upon which rests a horizontal bar (head-piece, balk or collar). Light poles are laid from bar to bar at intervals of about 18 or 20 inches, so that there

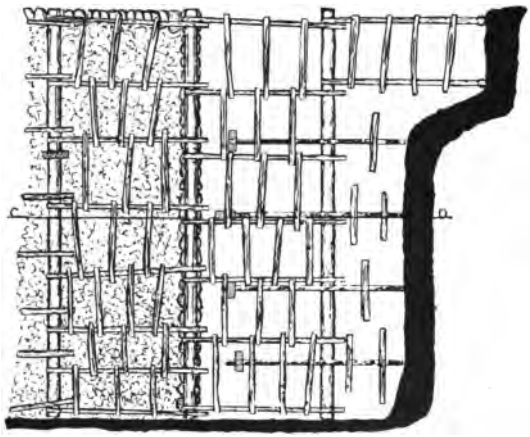


FIG. 84.—Courrières Method of Timbering.

is no unsupported roof space exceeding 3 ft. 3 in. by 18 or 20 inches. Similar light poles are placed between the props and the sides of the road if necessary.

3. **Working Places** (Fig. 84).—The arrangement in the case of working places is done most systematically and carefully. Bars 10 to 13 feet long, supported by props 3 ft. 3 in. apart, are fixed parallel to the working face; and, as soon as the face has advanced sufficiently, another line of bars is fixed in the same position (namely parallel to the face) and exactly 3 ft. 3 in. from the last line of bars. The roof between the two lines of bars is supported by light poles stretching from bar to bar and about 18 or 20 inches apart, as in the case of the

branch roadways; and where the roof is very bad, small cross pieces of timber are laid from pole to pole.

Iron Bars.—Between the last bar and the coal face, (which of course can never be more than 3 ft. 3 in.) the roof is still further supported by iron bars (*allonges*) 4 ft. 3 in. long by $1\frac{3}{8}$ in. square, the leading ends of which are flattened to a chisel edge. These are pushed forward until they almost touch the face. When an advance of rather more than 3 ft. has been accomplished with this additional support, light poles are put in, one end being supported by the last bar and the other by a light temporary prop close to the coal, and the iron bars are withdrawn. As soon as room enough along the face has been excavated for taking the full length of a fresh bar, no time is lost in putting it in under the forward ends of the poles and supporting it by the usual props; the temporary props used as provisional supports for the light poles are then taken out. The result is that the men work their faces forward and there is no space of roof unsupported exceeding 3 ft. 3 in. by 20 ins.

The foregoing is a brief description of the plans and methods rigidly enforced in regard to supporting roof and sides. Before closing this account, one or two other matters ought to be mentioned, as they undoubtedly contribute to some extent in producing the good results realised at these collieries. In the first place expense is put, as it ought to be, as a secondary consideration where danger is known to exist, and it is well known that at many collieries deaths from falls are nearly as numerous as from all other causes together. In the next place, wherever possible, all **goafs**—*i.e.* the parts of the mine from which all coal has been removed—are stowed completely full, though in some cases the material has to be brought from other parts of the mine. To such an extent is this plan adopted that fully two-thirds of the space left by the taking away of coal is tightly packed with some other material. There can be no doubt that this contributes materially towards the good results obtained. Another contributory cause of success is the absence of explosives in the getting of coal, there being no possibility of the timber being knocked out by shots, or the roof strata damaged, as is too often the case where explosives are used. The roof is thus very greatly protected.

The Supply of Timber.—General Rule 22 of the Coal Mines Regulation Act says: "Where the timbering of the working places is done by the workmen employed therein, suitable timber shall be provided at the working place, gate end, pass bye, siding or other similar place in the mine convenient to the workmen," and special Rule 47 says: "Where the timbering of the working places is done by the workmen employed therein, every workman shall by himself or his drawer take his own timber and other materials from the far end siding or the place whence he or his drawer takes his empty tub, except where the timber cannot be taken thence in or on the tub." In addition to this, the Home Office have recently in a New Special Rule (No. 3) compelled owners and managers of mines to keep a supply of suitable timber ready for use *in each working place*. It is evident, therefore, that the supply of timber is an important consideration, and it is generally admitted that the timber is best kept ready for use at the working place, where a systematic method of timbering is in force and the collier is careful to make a proper use of it. Where there is little room at the face, or where the collier is careless or neglectful, the most suitable place will be the gate end or siding. In the latter case, additional care and responsibility are placed upon the official whose duty it is to see that a good supply of suitable timber is distributed throughout his district. If the supply is inadequate, it becomes his duty to withdraw the workmen until a sufficient supply is obtained.

The Withdrawal of Timber.—The advantages of withdrawing the timber from the goafs have already been mentioned (p. 118). It is only necessary to add that along with the systematic setting it will be necessary to have systematic withdrawing of timber. It should be withdrawn before the faces have advanced so far as to make it unsafe to withdraw the back props, and to avoid the weight coming on the face. The regular withdrawal of the props is necessary if the setting of timber is to be also regular, and this, together with a good means of withdrawing them, will not only reduce the number of accidents, but will save a large amount of money. The systematic setting and drawing of timber and its many advantages have been discussed; it is only necessary now to refer to the various methods adopted of taking out timber.

A special rule is in force in some districts to the effect that: "No person shall withdraw or attempt to withdraw from out of any waste or from any heavy roof any timber in use for supporting the roof, except by means of a ringer and chain."

The Home Office has also pointed out to Colliery Owners and Managers that many accidents which now occur during the drawing of timber would be obviated if the use of the **ringer and chain**, the **dog and chain** or other similar device, such as are already in use in many districts, were made compulsory. These appliances, although often provided for the use of timbermen and wastemen, are not so largely used as is necessary if accidents are to be avoided.

Appliances for Withdrawing Timber.—In order to loosen and take out a prop or bar, the following simple instruments are used: pick, hammer or sledge, crowbar, jobber, rake, chisel, axe, and saw.

Unless a prop is exceedingly tight, a little chipping of the floor or roof at the foot or top of the prop and a blow of a large hammer or sledge should be sufficient. A crowbar may be necessary in some cases, and where the roof is likely to fall when the prop is withdrawn, the simple ringer or jobber may be used.

A **ringer** consists of a long iron rod with a slightly curved and sharpened end, and used for withdrawing props by an operator wishing to be some distance from the support.

A **jobber** is also a pointed instrument used for the same purpose.

The **rake** is also used for drawing timber from dangerous places, having a handle at one end and two pointed prongs at the other.

The **cutting chisel**, which serves for cutting the edge of the hollow of the post or prop in which the bar rests in cases where the prop cannot be knocked out, has a cutting edge at one end, and the opposite end is struck by a hammer or sledge.

The **axe** and **saw**, though chiefly used for cutting and shaping the timber, are also used in withdrawing.

All these appliances, however, are to a certain extent unsatisfactory, owing to the fact that the operator has to manipulate them in the immediate neighbourhood of the roof, which is dependent for its chief support upon the prop to be withdrawn. Consequently those appliances, such as the

following, which enable the timber-drawer to be in a place of safety while drawing, are much more satisfactory :

The **Ringer and Chain** or **Dog and Chain** (Fig. 85) consists of a ringer or handle of $1\frac{1}{4}$ inch round bar-iron, about 3 feet 8 inches long to the commencement of the crook (Fig. 85), the draw crook being 4 inches long. A hook is provided to which a $\frac{3}{8}$ inch link chain is attached, about 9 feet long. The leverage is about 10 to 1. After the prop to be withdrawn has been loosened by the pick, the chain is secured round it, being slipped through a large link at the end, the ringer fixed to a convenient fixed prop, and the loose end of

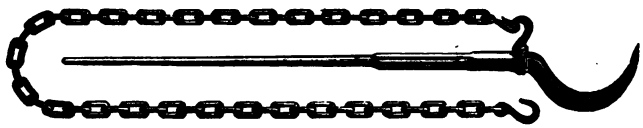


FIG. 85.—Ringer and Chain.

the chain attached to the hook in the ringer. The ringer is then worked as far as possible, the chain unhooked and rehooked so as to take up the short length of chain representing the distance pulled, and so on, until the prop is withdrawn.

Sylvester's Patent Prop Withdrawer.—The best and safest appliance for withdrawing props is undoubtedly that known as Sylvester's (Fig. 86). It is not only possible to withdraw props safely, but props which previously would have been considered too fast and secure to move, and prevented the uniform and necessary settling of the roof in the goafs, can now be easily drawn out by this powerful apparatus. It consists of a steel bar 3 feet long, $1\frac{1}{2}$ inches in depth and $\frac{5}{8}$ inch thick, with specially shaped notches about 1 inch apart and $\frac{7}{16}$ inch deep along one edge. A short chain (*A*) is affixed to this bar, by means of which it is attached to a firm prop. The notches of the bar form the fulcrum for a lever 3 feet long, made with a forked end through which pass two $\frac{1}{2}$ inch bolts, placed slightly over 1 inch apart. When the lever is drawn towards the fixed prop, the sliding block (*B*) is drawn from one notch to the next, being attached to the second bolt of the forked end of the lever. In this sliding block is a catch-bolt which falls into each succeeding notch,

the notches being shaped with a sloping side and a perpendicular side; this allows the block to move towards the fixed prop, but prevents it moving in the opposite direction. Any link of the chain (*C*) for withdrawing the prop is placed in a recess in the block (*B*). When the sliding block has been worked by the lever in this way from one end of the bar to the other, the chain can be taken from the recess, the block put back to the opposite end of the bar, the chain re-attached and the same operation repeated if necessary. To release the sliding block the lever is first pressed forward as if about to

FIG. 86.—Sylvester's Patent Prop Withdrawer.

make another stroke, the catch-bolt is raised and turned crosswise, and the lever quickly drawn from the notch. The leverage is 30 to 1, nearly three times that of the ringer and chain, and its weight is 30 lbs.

The appliance is also used for taking out tightly packed chock pieces, for drawing together the ends of ropes to be spliced, for liberating iron or steel bars, for drawing loaded tubs into position on the rails after being derailed, for liberating a coal cutter if accidentally jammed, and for pulling coal off at the face and lifting haulage ropes on to their pulleys.

Such a simple and effective means of saving timber in mines, without any danger to the timbermen, is of great value not only to the workmen engaged in drawing the timber, but to the employer. The saving of timber is considerable, often saving its own cost in a month, and the risk of life and limb is reduced to a minimum.

Brickwork, Masonry and Concrete.—Timber is not always suitable as a means of support underground, and it is sometimes necessary to use brickwork, masonry and concrete. The

shaft mouthing, sidings and the whole neighbourhood of the pit bottom are somtimes arched and finished in a permanent way by the means now explained. In constructing roads through extremely bad ground, or when forming air crossings, brickwork is often employed.

Materials Employed.—Bricks and mortar or concrete are most used, stone being chiefly used where bricks are difficult to obtain, and a good bed of sandstone is available or other suitable rock got from the mine or in the vicinity. Good, sound, hard-burned seconds bricks of good shape should be used. Mortar made from ashes and good slaked lime, and containing a large proportion of the latter, should be employed, though many managers prefer either dry walling or concrete. As in the walling of shafts, the use of concrete is a great advantage and is now often used.

Dry Walling.—In addition to the pack walls built of dirt and stones already referred to (p. 143), walls may be built underground of brick or stone without the use either of mortar or cement. If made of a good thickness, these dry walls serve as a good support for the roof, and when built need little attention or repair, and are certainly a cheap and efficient means of support where a large amount of suitable stones or bricks is available.

Brick Arches.—Where the roof is bad, brick arches set upon side walls of brick or stone are formed. When the roadway is being driven it is first supported, if necessary, by timber. The bricking of the walls proceeds immediately following the end of the roadway and the arch is constructed upon these walls. The thickness of the brickwork can be varied according to the nature of the strata, 14 in. work being most suitable in the case of mouthings and sidings; if the floor is bad, a much greater thickness, say 3, 4 or 5 feet, is advisable. All spaces behind the brickwork should be run with concrete or bricked solid throughout, the latter method preventing more efficiently than any other a movement of the strata. Side walls with semi-circular arches provide a support sufficient to withstand the pressure of the roof; but if there is side pressure in addition, a circular roadway of brickwork or masonry may be constructed, this form of roadway being the strongest for resisting pressure in all directions, though it is seldom necessary to resort to this expensive and inconvenient form.

Concrete.—Lime concrete is made of lime, sand, water and broken stones, etc., in different proportions; a convenient mixture is 1 part of quicklime, 2 of sand and 5 of stones or broken bricks. It is put into brickwork or masonry while in a semi-plastic or liquid state, and after it has welded together and become hard, forms a strong impervious bed or covering, serving not only to cement the bricks or stones together but to keep back water or running strata. Portland cement, mixed either with stones alone or with sand and stones, forms also a good concreting material.

Iron and Steel.—The great advantages of using iron and steel as a means of support are now being recognised. The great expense of this method has caused its adoption to be slow, but its great strength and permanency, and the later improvements in the manufacture of girders and props, have caused many colliery managers to take advantage of this excellent means of support. It is used chiefly in main roadways which have been found difficult to keep in good condition where ordinary timbering is used, and it is now recognised as one of the best supports for mouthings and shaft sidings, taking the place, to a great extent, of walling and arching. At the working faces also, in the form of props and bars, it is sometimes used and is found to withstand much greater pressure than timber.

Roadways.—Use of Iron and Steel Bars and Props.—Many main roadways require re-timbering every year or so when wooden supports only are used. These roads are consequently expensive to maintain. The use of iron or steel supports in such roads, although expensive in their first cost, may, however, be a great gain, as they may probably need little or no attention for some years.

The shape and size of bars will vary according to the length of span. Unlike timber, the strength of iron and steel girders chiefly varies according to section, as their width and depth may remain the same, while the thickness of the metal may be increased. A common and convenient size of girder for a low road, say 10 feet wide, would be 5 inches deep, 4 inches wide and $\frac{3}{8}$ inch thick. Where there is plenty of height, it would be advisable to increase the depth of the support, as a girder 7 inches deep would be considerably stronger. Similarly, the strength of the steel leg or stanchion will be increased according

to the increase in area of section. A convenient size of steel prop would be 5 inches by 3 inches by $\frac{3}{8}$ inch, and this is joined to the bar by means of bolts or rivets (Fig. 87). The weight of bars varies also from a few pounds per foot to 40 or 50. A convenient weight for bars 7 inches by $3\frac{3}{4}$ inches by $\frac{5}{16}$ inch would be 18 to 21 lbs. per foot, and a 10 feet span would bear a distributed load probably of 8 tons. Timber props weigh 17 to 19 lbs. per foot.

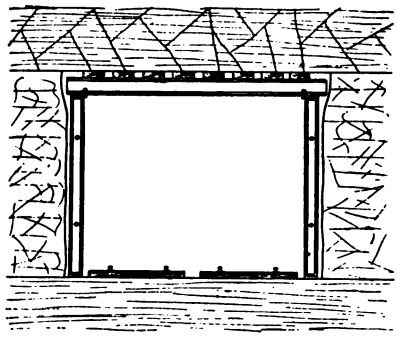


FIG. 87.—Iron or Steel Bars and Bar Legs.

Steel girders set upon timber legs (Fig. 88) are also used for supporting roadways, and in this form make a strong and trustworthy support. They can be fastened together by means of a large nail driven through a hole or slot in each bottom flange of the bar into the top of the prop. Where subject to considerable side pressure, an iron chair may be bolted to the girder, and the leg placed against this.

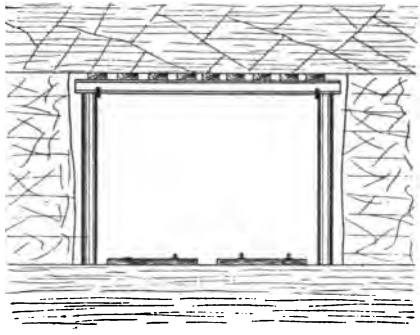


FIG. 88.—Iron or Steel Bars with Wooden Legs.

Mouthings.—Probably the most approved method of forming mouthings at the present time is by means of strong steel girders, set upon side walls of brick, and covered by steel boiler plates or wooden planks. It has long been recognised that an arched mouthing forms probably the weakest support at the point where the brickwork of the shaft rests upon it (p. 175).

It is necessary that the mouthing should be quite strong and secure, and that it should give the brickwork of the shaft solid and trustworthy support. As the mouthing begins to widen out from this point, the strength is gradually lessened, and the occurrence of side or lateral pressure tends still further to weaken the arching. By using steel girders, the last bricking ring can be laid upon a solid support, two girders being laid under the ring, parallel with the road, upon substantial walls; and these serve not only as a side support for the girders and covering afterwards put upon them, but as a foundation for the shaft. Two girders 12 inches deep by 7 inches wide, placed together, and repeated at intervals of 12 inches, covered with 2 inch pitch-pine planks or ¾ inch boiler plate, make a very satisfactory support. The walls should be of good brickwork 3 feet or 4 feet wide. If the floor is bad, the thickness at the bottom may be increased to 5 feet, and gradually decreased to 2 feet 6 inches or 2 feet at the top. If set in mortar containing a good proportion of slaked lime with ashes, it quickly becomes set, and the covering may be proceeded with as already described.

Faces.—Iron and Steel Supports for Working Face.—Bars set upon wooden legs may be used at the face in the same manner as they are employed in roadways; and are, indeed, now regularly used for this purpose. At the Lens Collieries, France, iron bars are used made of double iron about 4 feet long, weighing 11 lbs., and shaped, as shown in Fig. 89, by heating that end of the bar and flattening it out with a hammer until the two flanges are welded together. The wooden bars which are set parallel to the face, as in the Courrières method, do not rest flat against the roof, being prevented from doing so by wedges driven on the top. This method enables the iron bar to be pushed between the bar and the roof when the face has advanced about a foot; and the bar (Fig. 89) is constantly pushed forward as the face still further advances, the flattened end being against the roof, and wedges pushed upon the upper portion

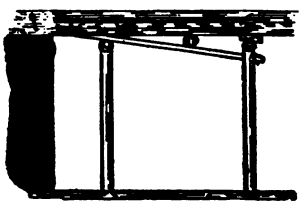


FIG. 89.—Method of using Iron Bars at the Lens Collieries.

of the bar on the side farthest from the face. These bars are placed thus every 20 inches, and when the collier has taken out 3 feet 3½ inches of coal, a light wooden pole is placed alongside the iron bar and supported at the face end by a temporary prop. Having holed a length of wooden bar 8 feet long, he puts in a new bar, supporting it by three regulation props, and then takes out the six temporary props.

Steel or iron props are not so commonly employed at the face, their great drawback being that they are broken before warning of danger can be given, and consequently are dangerous to the workman and expensive to the employer. Tubular or semi-tubular props introduced by Messrs. Spencer & Chambers, and made out of bars of H section are sometimes used. The flanges of the girder are hammered round so as to form a tube, and special means of plugging or closing the ends are adopted. In one case plugs are placed inside the tube and fastened by means of a pin; and in the other a cap with a rim is placed over the end and also secured by a pin. In order to avoid the sudden breaking of the prop under great pressure, the bottom of the prop may be tapered with a rounded end, in which case it may be said to have the advantages of ordinary tapered props.

Comparison between Steel and Timber Bars.—Various comparisons have been made between steel bars and timber bars as to their length of life. It has been said that the life of a steel bar is three times that of a wooden one. The experience of the author certainly confirms this statement as a minimum. Were it possible accurately to gauge the whole of the circumstances and conditions, it might be found that not only does the steel bar outlive three wooden bars, but that it is very considerably cheaper in the end. It must be borne in mind that there is a special class of work for which the steel girder is best fitted. It ought not to be used where timber is plainly the most suitable, any more than that a chock should be set where a prop will do equally well. The sizes of two classes of bars which the author has worked side by side are 5 inches deep of steel bars, weighing 21 lbs. per foot, and 8 inches deep of larch or Norway timber. The price of a 10 feet steel bar of such a size would be about 10s., and the price of a 10 feet wooden bar 8 inches square would be about 4s. The cost of setting in each case would be 1s. 6d. We then have the cost

of the bars 11s. 6d. and 5s. 6d. respectively. Leaving out of consideration the interest upon outlay in three years' time, we shall have

1 steel bar and setting, - - - 11s. 6d.
3 wooden bars and setting (3 at 5s. 6d.), 16s. 6d.

This shows a considerable advantage in favour of the steel bar. To this first advantage of cost may be added :

(*a*) Fewer stoppages through falls.

(*b*) When a road is done with, the steel bars can be used again, or sold as scrap, whereas broken timber is worthless.

(*c*) Less danger to workmen, owing to there being less work in connection with the taking out of old timber and re-setting of new.

To find the Strength of Bars.—The strength of a timber bar or beam varies directly as its breadth, as the square of its depth, and inversely as its length. That is to say, a bar 12 inches wide is twice as strong as a bar 6 inches wide of the same depth and length. A bar 12 inches deep is four times $\left(\frac{12^2}{6^2}=\frac{144}{36}=4\right)$ as strong as a bar 6 inches deep, and the same width and length ; and a bar 12 feet long is only half as strong as a bar 6 feet long of the same width and depth.

The formula, therefore, for obtaining the strength of beams will be $\frac{BD^2}{L}$. It is necessary, however, to take a coefficient for various timbers, as it will be quite clear that the breaking stress of all timbers will not be the same. These co-efficients may be taken as follows :

English Oak, - - - - -	15
Pine, - - - - - -	13
Beech, - - - - - -	13
Larch, - - - - - -	13
Fir, - - - - - -	12

Again, the breaking weight will vary according to the way in which a beam is loaded or supported, for it will be evident that a beam supported and fixed at one end will not bear so great a load if unsupported at the other ; in the same way a beam supported at both ends will not bear so great a load in the centre as a load distributed throughout its length ; nor will a

beam which is simply supported at both ends bear a weight as great as when supported and fixed at both ends.

We may say as follows, therefore :

K=	co-efficient of rupture,	with one end of beam fixed and other loaded.
$2K$=	do.	with one end of beam fixed and weight distributed.
$4K$=	do.	with both ends supported and weight in middle.
$6K$=	do.	with both ends fixed and weight in middle.
$8K$=	do.	with both ends supported and weight distributed.
$12K$=	do.	with both ends fixed and weight distributed.

The formula, therefore, for a beam fixed at both ends, with weight distributed, would be

$$W=\frac{12KBD^2}{L},$$

where W=breaking weight in cwts. ; K=co-efficient of rupture ; B=breadth of beam in inches ; D=depth of beam in inches ; L=length of beam in feet.

To find the Strength of Iron and Steel Girders.—The method in this case differs from the last because of the different shape of iron or steel girders and wooden beams. It is necessary to deduct the sectional area of space formed by the flanges.

The co-efficient of rupture may be taken as follows :

Steel, - - - - -	84
Wrought Iron, - - -	66
Cast Iron, - - - -	45

The breaking weight will again vary according to the way the beam is loaded.

The following formula may be taken for a beam with ends fixed and weight distributed :

$$W=K\frac{BD^2-2bd^2}{L},$$

where W=breaking weights in cwts. ; K=co-efficient of fracture ; B=breadth of girder ; b=inner breadth ; D=depth of girder ; d=inner depth.

Allow 68 per cent. of this if the ends are supported but not fixed; 50 per cent. if ends are fixed and the weight is in the centre; and 33 per cent. if the ends are supported and the weight is in the centre.

Note.—As already stated, it is necessary to allow only 50, or at most 70 per cent., of the result as a *safe load.*

Questions on Chapter VIII.

1. What kinds of timber are employed in this country for supporting purposes in mines, and how should the timber be stored at the surface? (1901.)

2. Describe and sketch the following timbers: Prop, sprag, bar, lid, chock, cog, cockers (cocker meg, cocker sprag).

3. What is Hepplewhite's system of preparing timber for supporting purposes in mines? What are its merits, and in what collieries can it be used to the greatest advantage? (1901.)

4. Show by means of a plan and two sections how the roof and face of the coal can best be supported by systematic timbering in a longwall face, say 30 yards wide from centre to centre of two adjacent roads, assuming that the roof requires to be supported and the coal to be holed. (1900.)

5. Write out as nearly as you can the Special Rules concerning timbering which have been established at any colliery with which you are acquainted. (1903.)

6. State the advantages and disadvantages of taking out the whole of the coal and withdrawing the props.

7. Describe any method with which you are acquainted, of propping at the face, giving the sizes, position of props, pack walls, chocks, rails, sprags and drawing roads.

8. In clearing up after a heavy fall in the main haulage road, show how you would secure the roof where it has come down for a considerable unknown height in faulty ground, and what precautions you would take.

9. Describe the method of timbering at the face with iron bars adopted at Courrieres. What effect is it reported to have had on the death rate from falls? (Newcastle.)

10. When withdrawing timber, what precautions would you take (*a*) when loosening the timber; (*b*) when removing it from the fall? What tools do you consider necessary for this work? (Manchester, 1901.)

CHAPTER IX.

HAULAGE.

THE **haulage** of the coal from the workings to the pit shaft is done to a great extent by ropes or chains controlled by machinery. The roads along which the tubs containing coal are drawn are called **Engine Planes** or **Main Haulage Roads.** It is impossible to employ ropes along all underground ways; consequently, it is necessary for the miner or his drawer to haul the coal along the faces and drawing roads, and to arrange for the hooking-on of his full tub, and the detaching of his empty one, to or from the rope.

Mine Waggons, Rails, Sleepers, etc.—Ancient Methods.—In the early days of coal mining it was the custom to carry the coal in baskets from the working face to the shaft, in the same manner as it is now conveyed by women in all Indian mines. As the distances between the shafts at that time were not great, it was just possible to carry the coal, though the labour was great, the body of the bearer having to sustain the whole of the weight whilst in a stooping position. Owing to the increasing depths of the shafts, and the consequent increase in the cost of sinking and maintaining them, fewer shafts were employed for a given area, and thus the distances from workings to shaft became greater, and the means of conveying the coal to the shaft became an important question. Barrows were tried for a time, but these were eventually superseded by the employment for the main road of the tram with wheels running upon rails, and of a small wicker basket, or wood tub, in the case of the coal face. These baskets or tubs were drawn by boys or men, and in some cases by women and girls, by means of a belt and chain, the belt being fastened around the waist and a chain being used to connect this with the tub. In this case the drawer generally

went along with his hands on the floor and the chain between his legs. In other cases the boy was not exactly a drawer, though called such, but a "pusher-up," as he was behind the tub pushing it with his head uphill. Necessarily, better and more expeditious modes were employed as distances and quantities increased, and methods of drawing and pushing are rarely seen now except in very special cases, whilst all female labour underground has been prohibited for half a century. It may be mentioned here that at one period in certain mining districts two sizes of tubs would be in use at one time; one tub on wheels, and holding twice as much as the other, being used for main roads where extra roof or floor had been taken out for room; the other, without wheels, being confined to the working place where there was less height, and being filled and emptied twice into the larger tub, which was then taken to the shaft. The extra cost of making holes for the larger tub to stand in, together with the breakage of coal in emptying from one tub to the other, led to the gradual abandonment of this plan.

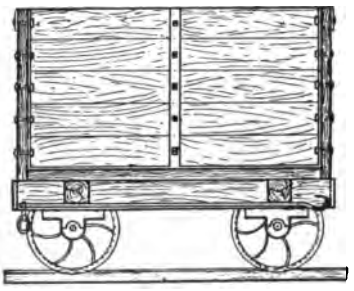


FIG. 90.—Wood Tub, Corve or Hutch.

Tubs.—Tubs with wheels (also called *mine waggons*, *hutches* and *corves*) having come into general use, it next became a question as to the best form and most convenient size to make them. Generally it may be stated that a rectangular shape with the longest side in the direction of the road seems to be for the most part adopted. In the matter of the height, the thickness of the coal seam necessarily affects this to some extent. In the case of a thick seam, where there is sufficient room for a high tub, no difficulty of course exists, and the height considered most suitable can be adopted without extra expense in roof or floor. But in the case of thin seams, if much coal is to be brought out, the tub will probably have small wheels, whilst the required capacity will be obtained by making the tub longer and wider, and smaller in height.

In modern collieries, tubs vary in carrying capacity from 5 or

6 cwts. to 15 cwts., but in estimating the space required in the tub for these weights, it must be borne in mind that coal in the broken condition occupies a greater space than whilst in the mine solid.

Capacity of Tub.—In order to estimate the cubical space required in a coal tub for a given weight, we may take the following calculations as approximately correct:

Specific gravities of solid coal (excluding the heavy Anthracites), from 1·25 to 1·33, water being 1, average sp. g. 1·29.

Weight of 1 cubic foot = $62{\cdot}5 \times 1{\cdot}29$ = say 80 lbs. Now, the weight of coal in the broken as compared with coal in the solid, is approximately as 3 to 5. Hence, we have $\frac{80 \times 3}{5} = 48$ lbs. per cubic foot as it is when in the tub.

A very convenient size and shape of coal tub for mines of about 3 ft. in thickness, is one holding 6 cwts., and measuring inside 3 ft. 6 in. by 3 ft. 0 in. and 1 ft. 4 in. deep. For tubs of greater or less carrying capacity the dimensions may be kept in these proportions, or may be varied to suit the thickness of the seam and the character of the roof—a thick seam allowing greater height of tub, and a good roof a greater width. The material of which the frame and body of the tub are made is mostly wood (Fig. 90), but in many districts iron (Fig. 91) is beginning to be used, especially in deep and dusty mines, where it is very necessary that as little dust or small coal as possible shall drop through to the floor—this dust being now recognised as amongst the dangers of the mine. The wheels are of steel, and are now made fast to the axles, one source of friction being thus done away with. The tubs are connected to each other, when running in gangs, by means of couplings fastened to the central drawbar of the tub at each end. Each coupling consists of two or three iron links and a hook, and connection is, of course, made

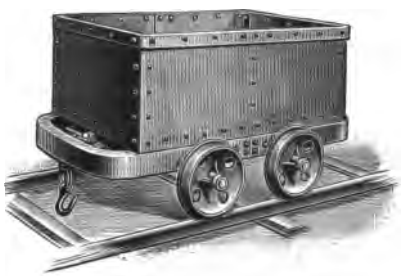


FIG. 91.—Iron Tub.

by the hook of one tub being dropped into or through a link of the next tub. Each tub of coal is claimed by the person who fills it by means of a tin or iron tally bearing his own number, *i.e.* the number by which the person is distinguished in the books of the colliery. This tally is fixed generally by a string to a hook in the tub bottom before any coal is filled in, the hook being inside the tub and the tally hanging outside, so that the browman, as he runs the tub from the cage to the weighing machine, may call out the number to the man who weighs the tub and its contents, and he can then book the weight to the individual who is known by that number.

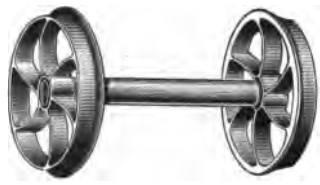


FIG. 92.—Wheels and Axles for Inside Pedestals.

Wheels and Axles. — Tubs were formerly employed having fixed axles and moving wheels on their extremities, free to move independently of each other. Now, however, the most common arrangement is to have the wheels fixed upon the axles, both revolving together and secured by means of a pedestal to the under side of the tub. They are made either with inside or outside bearings. Fig. 92 shows an axle arranged for pedestals to be fitted inside the wheels, a method most generally adopted. Fig. 93 shows axle and wheel arranged for pedestals outside of the wheels.

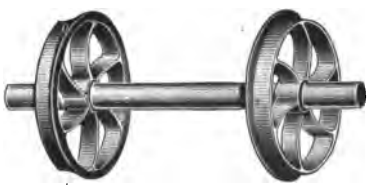


FIG. 93.—Wheels and Axle for Outside Pedestals.

Pedestals.—These vary in form according to their position ; for wheels with inside bearings, a suitable self-lubricating pedestal is that shown in Fig. 94 ; for outside bearings the pattern shown in Fig. 95 is used. The lubrication of these wheels is important, and it is necessary to have good

FIG. 94.—Section of Pedestal for Tub.

FIG. 95.—Section of Pedestal for Tub.

means of effecting thorough lubrication. As the pedestals are constructed with a chamber under the axle holding the oil, the axles are protected, the oil being supplied constantly to the bearings by wool or hair felt fitted close against them.

Patent Tub Greaser.—A method of greasing tubs in use at many collieries is that shown in Fig. 96. By this means the services of youths are dispensed with, but unless care is taken a large amount of grease may be lost. The greaser is fixed at a convenient place near the cages and kept filled with grease, and automatically deposits this on the axles as the tub passes over; greasers can be arranged for either inside or outside bearings, and are used whether tubs are fitted with strap pedestals or not.

FIG. 96.—Patent Tub Greaser.

Pulleys and Rollers.—For preventing the rubbing of the rope upon the ground, small **pulleys** fixed in frames (Fig. 97) or **rollers** (Fig. 98) are used. The former are fixed where the

FIG. 97.—Pulleys for Guiding Rope.

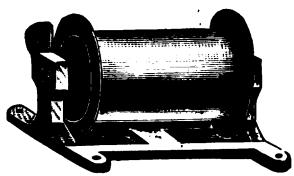


FIG. 98.—Rollers for Rope Haulage.

rope has to pass round a curve, or they may be fixed against the roof in ordinary roadways. **Rollers** are placed at short intervals between the rails in brows or levels. Light, strong, true-running rollers, which revolve with the slightest touch, make an enormous difference to the life of a rope. They are made as a rule with barrels of rolled steel and steel spindles.

Rails.—The rails now used on main underground roads closely resemble those used on the railway systems, only they are made of smaller section, and where there is what may be called heavy traffic, the lengths and strength of the rails are constantly being increased to the fullest extent practicable. Two forms of rails are in general use underground, **flange rails** and **bridge rails** (Figs. 99 and 100). Both these types of rail sections are also shown in Fig. 101. The left-hand figure is a flange or tee rail and the right hand a bridge rail. Flange rails may be joined together by means of fishplates and bolts; or,

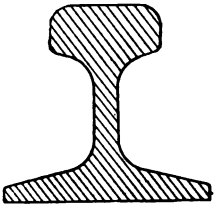


FIG. 99.—Flange or Tee Rails.

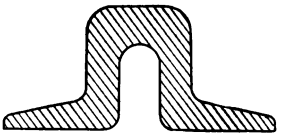


FIG. 100.—Bridge Rails.

in the case of steel sleepers, may be secured with a spring clip fastener *C*, as shown in Fig. 101. Bridge rails are secured in the case of wooden sleepers by nails driven through holes in the sides, or secured to steel sleepers, also as shown in Fig. 101. The rails vary in weight from 10 lbs. to 18 lbs. per yard, and are made in different lengths. Besides the main roads of a mine, there are smaller or secondary roads, and there are also the roads along the faces which have to be provided with rails; but these not being permanent roads (those at the faces in particular having to be constantly moved) they must be sufficiently light to be handled by one man. There are various types, mostly of wrought iron and of bridge section, for this work, their weight varying from about 10½ lbs. upwards to the yard for a single rail. For use on main haulage roads the length is generally 12 ft., but along the face they are shorter, 6 ft. being much more convenient.

Sleepers.—Good strong sleepers of wood are most common, and these should be soaked in a solution of creosote and tar before being employed. The Buckled Steel Sleeper shown in

Fig. 101 is a good form for hard roads. Bagnall's Corrugated Sleeper with riveted clips are also used in many mines, both of these forms being made by Messrs. White, of Widnes. The chief things to aim at are that the rails shall be strong; that the joints shall be as true and immovable as possible; be secured

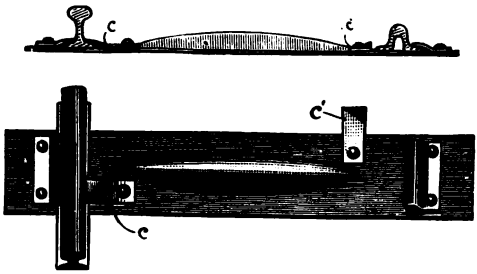


FIG. 101.—Bagnall's Corrugated Sleeper.

by the fishplates and bolts at each rail end, with spikes at intervals between; and the sleepers of wood or iron shall be carefully laid and fastened at the ends. It has to be remembered that in some places heavy gangs or trains of coal are brought up at great speeds, and sleepers moving about or joints of rails being imperfect may mean damage to a number of tubs, loss of coal and waste of time.

Points, Crossings and Shunts.—From all main roads of any considerable length there branch off at intervals other

FIG. 102.—Points for Train Lines on Main Roads.

roads to right or left. In former days, these branches were started by the laying of an iron plate with strips of iron known as **guiders** to guide the tub on its passage from the plate to another set of rails. These plates, called **landings**, are still

necessary at the working faces, but are now seldom seen on the main roads. Their place is taken by rails of the same strength

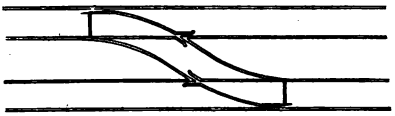


FIG. 103.—Points for Main Roads or Pit Bottom.

and type as the main lines, but curved or bent, and carefully fitted to allow the tubs to pass from one line of rails to another without danger of getting derailed. **Points, crossings,** and **shunts** are the terms applied to these special lines. The

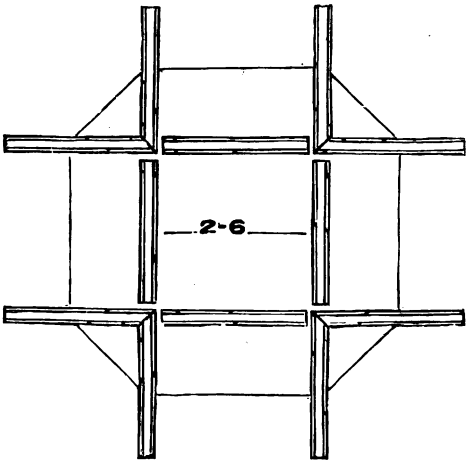


FIG. 104.—Right-angle Crossing for Haulage Road.

diamond crossing is a convenient form of crossing for single roads, and the two-way points with switches and crossings built on steel sleepers, shown in Fig. 102, are suitable for pit bottom or main roads, though the lever is often dispensed with and the points moved with the foot (Fig. 103). Fig. 104 shows a right-angle crossing which can be used in conjunction with plates at the junction of two roads which cross each other

at right angles; the width between the rails is shown as 2 ft. 6 in., but this is regulated according to the width of the

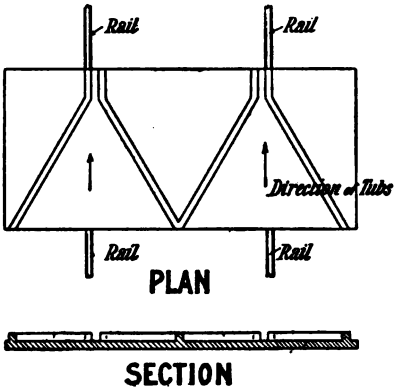


FIG. 105.—Guides for putting Derailed Tubs on to Rails again.

tub. Tubs continually get derailed during hauling, and great labour and expense are involved in consequence. In Fig. 105

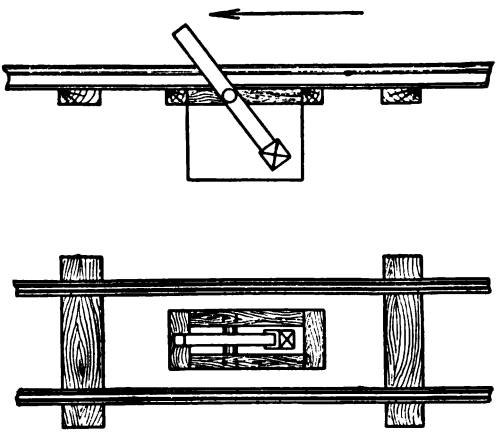


FIG. 106.—Catch or Stop Blocks.

is shown a simple set of guides for mechanically putting the tubs on the rails again, in case of derailment,

Tub Controllers.—Some means of holding the tubs back is necessary, not only during the loading and unloading of the cages, but also at the top of inclines and at other points on the haulage roads.

Where the road is level at the top of an incline, **catch blocks** (Fig. 106) may be used, and in addition to these large wooden

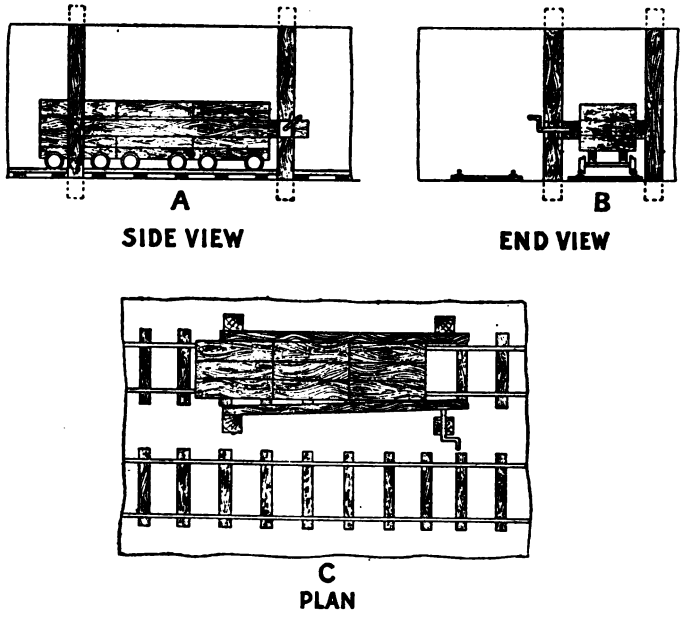


FIG. 107.—Squeezers for holding Tubs at Top of Incline.

chock blocks may be stretched across the rails, kept in position until the gang is ready to run down, and knocked out when required.

Squeezers are sometimes used, which consist of two thick horizontal timbers (Fig. 107), supported on posts and placed parallel to the rails at a height of 2 ft. or 2 ft. 6 in. from the floor. At the end nearest the brow is fixed an extra strong post with handle and screw, by means of which the tubs can be screwed up between the horizontal timbers and held in position until

the tubs are ready. By slightly loosening the timbers, one or more tubs can be safely let down at a time, this method being safe even for the steepest gradient and with almost any number or weight of tubs.

Patent Tub Controller.—M'Bean & Eaton's patent tub controller (Fig. 108) is used for controlling, retaining and releasing one or more tubs just as required. This arrangement may also be used either for loading and unloading the cages or upon a line of rails. The mode of working is simple. A dozen detached tubs, for instance, may be held upon an incline by the apparatus until it is desired to allow a couple of tubs to pass;

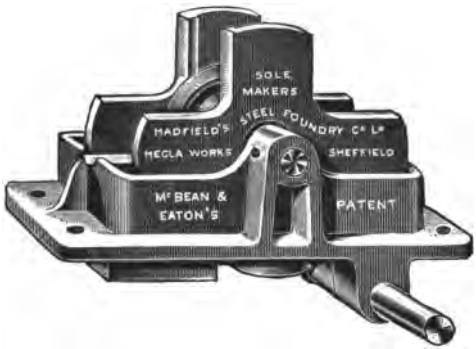


FIG. 108.—Patent Tub Controller.

the lever of the apparatus is then moved by hand—or by a wire if from a distance—upon which the four axles of the two tubs cause the barrel to revolve, until having made a complete revolution, it is stopped by the catch coming into position against the shoulders of the barrel, the two arms of which block the passage of the third and remaining tubs. A trustworthy controller of this kind is of great convenience, saving considerable labour, especially where it can be arranged to act automatically by the cage settling on the keps.

Brake Jig Pulley.—For use on self-acting inclines, some means of controlling the speed of the tubs is necessary. This can be done either by a foot or hand brake provided with a lever where the inclination is great, and the tubs heavy or large in number. Brakes of this kind necessitate the erection of a

wooden frame, the brake, with either a wood or iron brake strap, being applied to the wheel or the drum as the case may be. A handy and simple brake pulley is that shown in Fig. 109, but this requires no framework, being readily fitted by means of a short chain to a prop fixed securely on the landing. Its action, as will be seen, is quite simple, pressure being applied all round the rim of the pulley when the handle is screwed up; the brake block clears the pulley immediately the brake is released. For its size, and considering the ease with which it is set up, it is a most practical and trustworthy jig pulley. The form shown is made by Messrs. Oldham & Sons, of Bury.

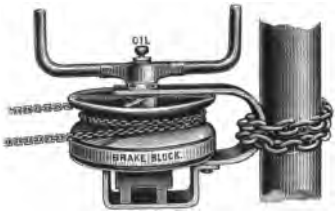


Fig. 109.—Brake Jig Pulley.

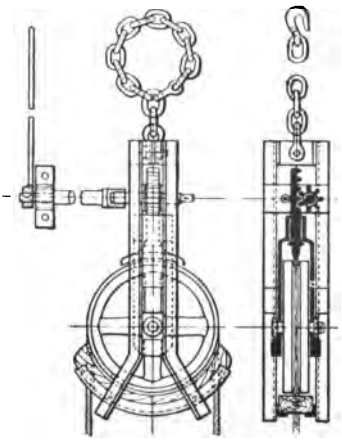


Fig. 110.—Beien's Brake Blocks.

Beien's Brake Blocks.—For working on inclined planes there are few safer or more convenient brake-blocks than Beien's (Fig. 110). The essential parts of it are: a frame made of angle iron, which carries on the top a hook or chain for fixing the brake block on a prop for use. On the bottom a wooden brake block is placed, against which the rope pulley with brake surface is pressed by the pull of the hauled load. The brake pulley is about 17 inches diameter, and is guided in the frame by slide bearings, the latter being fitted with flat bars above the pulley, and are joined together by a toothed bar, in which a pinion gears. The axle of the pinion outside its bearings is formed square, and a hand lever with a square

hole is used to turn the axle, whereby the pulley is lifted from the brake block and commences its revolutions. By turning the hand lever in the opposite direction, a brake claw formed on the under part of the toothed bar is pressed against the haulage rope in the groove of the pulley, causing an immediate stop of the running tubs. In order to prevent the rope when slack from leaving the pulley groove, it is conducted through a slot in the wooden brake block, and its outward motion is limited by bolts. The brake does not possess any prominent parts likely to be damaged; it is extremely powerful, and the easy and gradual manner in which it can be applied prevents all shock and liability of the tubs being derailed.

Haulage Clips.—There are so many different kinds of clips used for attaching the tubs to endless ropes, that it is impossible to describe them all. **Haulage clips** are used where it is desired to attach and detach the tubs to or from the rope as readily and safely as possible Owing to the twisting of the haulage rope, the ordinary way of *lashing* the short chain to the rope by giving it a few turns round the rope and fastening the hook tight is found to be inconvenient and in many cases dangerous. There is no doubt, however, that for use on varying gradients, and for passing round pulleys, this method is very often successful. But in order to gain the same end more readily and securely, special clips have been substituted which have dispensed altogether with both hook and chain, or clips have been attached to the end of the chain instead of the hook. Most clips obtain their grip upon the rope owing to the frictional contact obtained at two points when simply placed upon the rope; the movement of the rope and the tightening of the chain being sufficient to hold them in position. But there are also clips designed to grip the rope when pressure is put upon side clamps by means of a screw or lever. It will be sufficient if we describe two forms of efficient rope clips.

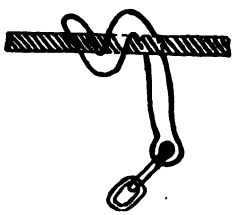


FIG. 111.—Patent Coil Clip for Endless Rope Haulage.

The Patent Coil Clip.—This simple and handy clip (Fig. 111) is designed for use on long haulage roads where a large number of clips are necessary, and also for those ropes which are liable to

twist in such a way as to render large clips impossible. It is impossible for the clip to twist with the rope, and there is no doubt this is a great advantage, as a lashing chain is extremely awkward to unlash if it becomes twisted, and a clip which does so is unsafe. Its grip upon the rope is obtained by frictional contact, the grip being increased according to the pulling strain upon the short arm. The clips are readily slipped on to the rope, which they grip securely immediately the chain becomes tight, and they can be taken off in much less time than is

Fig. 112.—Smallman Haulage Clip.

required to take off a lashing chain. They are used for both over and under-tub haulage.

The Smallman Clip.—This clip (Fig. 112) is made in different sizes, varying from 12 to 20 lbs. in weight, according to the load and gradient. The levers are made of drop-forged steel, other parts being of special steel. The principal, doubtless the only, faults in the original pattern were that the central bolt soon became bent, and the screw thread on it bruised to such an extent as to render it impossible for the nut to be adjusted with the fingers—serious faults by no means easy to overcome. However, a new pattern has now been brought out, in which these defects do not exist. There are two outside collars with

trunnions. The bolt turns freely in one collar, and engages with a screw-thread in the other collar. Thus the shells rock on the trunnions and cannot put any bending strain on the bolt; neither can the screw-thread on the bolt get damaged. A spiral spring is placed between the shells. When the handle of the lever is in the raised position, the bolt can be turned readily by the fingers without removing the clip from the rope. The adjustment of the clip to the rope is therefore easy. Suitable couplings are employed, a short hook being sufficient where the strain is in one direction only during the journey, but if it be necessary at some part to hold back the tub, a coupling 3 ft. or even 4 ft. long is substituted for the short hook. When the lever is pressed hard down, a good strong grip is obtained upon the rope. This lever is provided usually with a balanced safety catch that falls into its working position automatically. The catch, when turned back out of action, stays back until the lever has been raised, so it is no trouble to manipulate. For heavy gradients the bolt is adjusted so that both hands are required to depress the lever, thus ensuring a tight and safe grip.

Transmission of Power.—In addition to the power required for the haulage of coal underground, power is needed for other purposes, such as **Pumping, Coal Cutting** or **Drilling** and **Ventilation**, and the powers employed may be **Steam, Compressed Air** or **Electricity.**

Up to the present time **steam** has been the chief power employed in and about collieries. Steam is in many cases a convenient power, but it cannot be taken far into the workings, nor be used for coal cutters or drilling at the face, owing to its bad effect upon the roof in causing it to disintegrate or break up. On the other hand, steam is cheaper than compressed air or electricity, and as it is also needed for driving purposes, even where the latter powers are used, it must be looked upon as essential at almost all mines.

Compressed Air.—There is no doubt that compressed air, in spite of some drawbacks, is one of the best means of transmission of power in coal mines. The fact that it is the safest means is sufficient to entitle it to great consideration, and its disadvantages should in many cases be overlooked in favour of this good quality. In addition to its safety, however, the ease with which it is transmitted, its easy application to common

engines, its use for so many different purposes, its comparative cheapness, all these are considerations which outweigh its chief disadvantage of loss of power owing to friction during transmission.

Electricity.—As has been seen, electricity can be applied to almost every kind of work, including not only pumping, hauling, coal-cutting and ventilating, but general surface work also, including the driving of screens, workshops, washeries and even winding engines. Quite apart from the utility of electricity for overcoming disadvantages of the underground surface conditions, electricity is in itself a serviceable, effective, convenient and economical motive-force. For lighting purposes also, both above and below ground, and in sinking pits, electric power is superior to other forms.

The various purposes for which these powers are required may next be considered.

Pumping.—The pumps used are either steam, air, or rope driven. Steam, as has been said, can only be taken a short distance from the shaft, and consequently for any considerable distance in, compressed air or ropes were, until the introduction of electricity, the only means available. With compressed air the outlay upon the compressed air pipes and the leakage and loss of efficiency have discredited this form of pump. Probably the handiest pump for most of the conditions appertaining to long distances underground has been the rope-driven pump. This again often necessitates special ropes from the hauling engine to the pumps, or, if driven by the haulage rope itself, often means the running of the haulage rope for pumping purposes only.

Coal Cutting and Drilling.—The motive power for this work is either compressed air or electricity. Splendid results have been obtained by the former method, and many collieries, notwithstanding electricity, are putting down high-class modern compressed air plants for the purpose of driving coal-cutters and drills. In many mines it is the only motive power which can with absolute safety be adopted at the coal face. The outlay and upkeep of compressed air pipes for an extensive mine is, however, very great. To overcome this disadvantage, and to retain compressed air on the face, it has been found advisable in some cases to take the electric current to a point near to the face where the cutter is working, and by this

current to drive a plant for supplying compressed air to the cutters and drills in the workings.

Ventilation.—Steam-driven fans are most commonly used, but since the great advantages of electricity for colliery work have been recognised, many electrically driven fans have been erected, and there is no doubt that in the future many mechanical ventilators will be driven in this way. It often occurs that the upcast shaft is situated some distance away from the winding shaft, or there may be a number of small shafts having communication with different seams, each requiring a comparatively small fan. To put down a steam-driven fan in each of these cases would mean a great outlay in steam pipes or boilers, while on the other hand, small cables are easily run from a central electric-power station to small motor-driven fans.

Haulage.—For considerable distances the same objections obtain for haulage engines that are found in pumping. The extended application of the endless rope haulage underground has greatly facilitated the driving of bye-roads or secondary roads near the extremities of the main roads, but the driving of these roads by means of friction or jaw-clutches from the main rope pulleys has its economical limits. Many occasions arise when it would be an advantage to put down a small detached haulage in some district or section of a mine, such as on a level off a long main-jig brow, or in a part of a mine which has been thrown up or down by a fault.

Various Systems of Mechanical Haulage.—The systems at present in use are known as :

1. The Single Rope or Road.
2. The Endless Rope or Chain.
3. The Main and Tail Rope.

The Single Rope System (Fig. 113) is that where a train or gang of tubs is run down hill empty, being held by a rope, and afterwards a train or gang of full tubs is brought up the same brow. The advantages in this case are :

(1) Only one line of rails is required.

(2) The road may be narrower, less costly to drive and requiring less timber to support.

(3) Besides the tubs necessary between the brow and the working faces, only three gangs of tubs are required, one at

the top, one at the bottom and the one on the road going up or down.

(4) Only one length of rope, a little more than the length of the brow, is required.

FIG. 113.

The disadvantages are:

(*a*) That the force of gravity, which by another system is available, does not assist the engine.

(*b*) The speed is generally required to be great, and this is to some extent a source of danger.

(*c*) It can only be applied to brows, and those must be of a certain gradient.

The Endless Rope or Chain (Fig. 114).—In this system a rope or chain passes round a driving pulley either on the

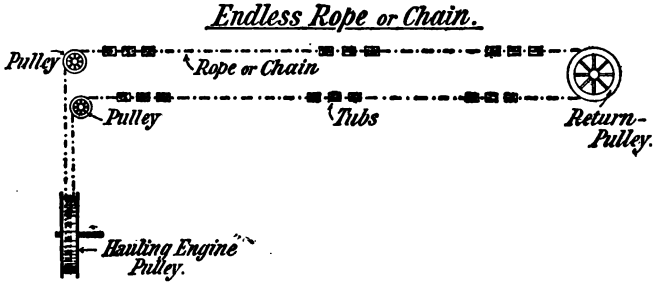


FIG. 114.

surface, and from thence down the pit to a pulley near the bottom of the shaft; or, the driving pulley may be near the pit bottom, whence it passes along the main road or roads towards the working faces, and being coiled round a pulley there, is brought back to the driving pulley, thus forming a complete circuit or endless rope, as the term is. In some

cases, instead of a rope, a chain is used. This is more frequently the case where tubs are taken long distances on the surface. The most common, and probably the best, way to apply this system is to attach two tubs to the rope at regular distances, say 20 yards apart all the way in and out; of course, on one side the empty tubs would be going from the shaft to the workings to be filled, and on the other side the full tubs would be coming from the workings to the shaft to be sent up and emptied.

When all is in readiness, and the tubs on each side are attached, the engine is started, in some cases 150 or 200 or more tubs move slowly out on one side, and on the other the same number move slowly in. As each pair of tubs reaches the shaft they are uncoupled from the rope and run into the cage, at the same time that two tubs are brought from the cage and put to the rope on the other side to go into the workings. The advantages of this system are:

(1) Its slow motion is a source of safety.

(2) It gives a constant supply of full tubs at the shaft and of empties to the collier all the day through.

(3) It utilises gravity which in the single rope is lost.

Its disadvantages are:

(1) It requires a double width of road.

(2) It requires a double length of rope.

(3) It needs a greater number of tubs in the brow at one time.

The Main and Tail Rope System (Fig. 115).—In this case there are two drums and two ropes. Upon one drum is wound the rope which pulls the gang of full tubs from the workings to the shaft; on the other, a rope used for the purpose of pulling the empty tubs from the shaft to the workings. The hauling engine and drums are either on the surface or at the bottom near the shaft, the former position being most desirable. The method of working is as follows:—Suppose the gang of tubs 10, 15, 20, or any other number, to be standing empty near the shaft ready to be taken to the workings. The rope, which is on what may be called the full side, is attached to the gang on the side next to the drum, whilst the rope of the empty drum is attached to the same gang of tubs, but at the end

next to the workings, and thence passes round a pulley at the "far end" and back to the empty drum. The two drums are on the same shaft and moved by the same engine. When, as in the case here assumed, the empty gang has to be drawn to the far end, the empty drum is, by means of a movable clutch, put in gear with the engine, the other drum running loose upon the shaft; the engine is then started, the empty drum coils its own rope upon itself, thus pulling the tubs towards the "far end" and the full rope with them. Arriving

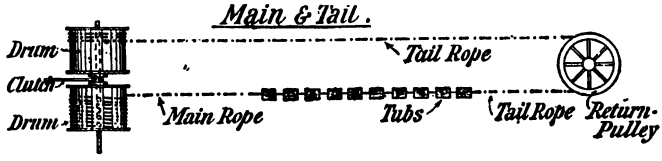


FIG. 115.

at this "far end" the empty rope is detached from the empty gang and attached to the full gang in the same position as before, when the other rope is treated similarly. The full rope is now ready for pulling the gang of coal to the pit shaft; the empty drum is put out of gear on the shaft to run loose in its turn and the full tub in gear. The engine is started and the coal comes to the shaft, and so on the day through. The chief utility of this system is, that it can be used on a perfectly level road or on an undulating one; it requires only a single line of rails; the empty rope need only be a small, light one, comparatively, and if the rails and road be kept in good order it works easily and with regularity.

Signalling.—An efficient means of signalling is almost as necessary on haulage roads as in the shaft. For this purpose there is no doubt that electric signalling is the best. Two wires run along the side or roof of the roadway, and they are connected to bell and battery in the ordinary way. The only point in which mining signals differ from house installations being greater strength and more tightly-fitting parts. The bells are either single gong or continuous ringing. They are specially constructed for mining work, fitted on paraffined teak bases, in cast-iron frames with detachable cast-iron covers; the coils are of best silk-covered wires, the whole made damp-

proof and dustproof. The current is furnished as a rule by batteries of the Leclanché type, either open or dry cells. In some cases the current is supplied from accumulators charged from the wires supplying the lights. Signals are given by merely pressing the bare wires together at any part of the roadway. In some cases the wires are insulated, and it is only possible to bring the wires in contact at certain portions of the road called signalling stations.

Compressed Air Locomotives.—Compressed air locomotives, though not common in British mines, are used in several mines in the United States. There is no doubt that a method of haulage which enables tubs to be brought from the coal face to the shaft without changing is extremely serviceable in mines, but this is only possible where compressed air or electric locomotives can be employed. It is a great advantage also to be able to shunt or to run either way at certain points on the roads. This is possible where a locomotive accompanies the trip, and in case of tubs getting derailed it is a distinct gain to be able at once to pull up and so prevent further damage. On the other hand, rope haulage for steep gradients can hardly be improved, and heavy locomotives are impossible in steep brows.

For compressed air haulage the following are required :

(1) A locomotive of suitable weight and power constructed to carry sufficient compressed air for requirements.

(2) Charging stations.

(3) Stationary reservoir, which may be a pipe line, where long runs exist, or one or more storage tanks when runs are short. The air is compressed in this system of storage while the motor is making its trip.

(4) The usual air compressing plant.

The general mechanism of a compressed air locomotive is similar to that of an ordinary steam locomotive, except that the bearings are larger. Instead of water tank, boiler and firebox, however, an air locomotive is equipped with strong storage tanks charged with compressed air at a pressure of 700 to 1,000 lbs. to the square inch or more, and arranged with regulators and automatic stop valves for conveying the air to the cylinders at lower pressures. The following are the chief sizes in a compressed air locomotive

drawing 16 cars, each holding 2 tons, along a road 1,000 yards long, heaviest gradient 1 in 30, and returning with empty gang, with one charge of air. Cylinders, 7 in. diameter; stroke, 14 in.; rigid wheel base, 5 ft. 3 in.; weight, 18,500 lbs.; length over all, 17½ ft.; width, 5 ft. 2 in.; height, 5 ft.; working pressure, 600 lbs. In spite of their great length they negotiate curves, say of 20 ft. radius, with ease.

Electric Haulage.—For main and secondary haulage roads, electric hauling engines, fixed either at the surface or near the bottom of the shaft, are now often employed. Large horse-powers are sometimes required, if it is necessary to haul the

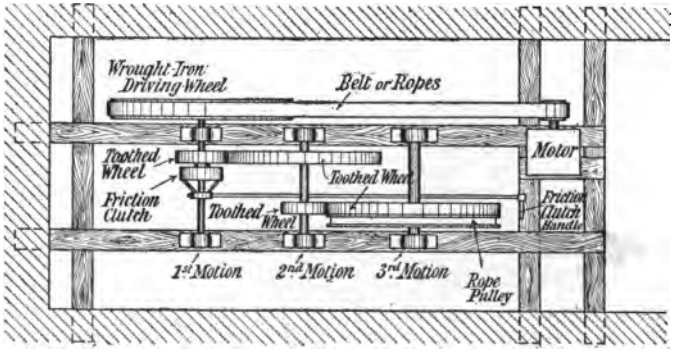


FIG. 116.—Electric Hauling Engine.

tubs up brows or if a big load is put upon a fairly long rope. Many good motors of from 10 to 100 effective horse-power are made, and it is seldom that larger powers than the latter are required. The ordinary haulage plant is used, an electric motor being simply substituted for the steam or compressed air engine, and connected to the pulley by means either of spur or worm gearing, or a belt or ropes may be used to a first-motion shaft.

Electric-Hauling Engine.—In Fig. 116 is shown a good form of electrically driven hauling engine suitable for endless rope haulage. It is mounted on a framing of timbers 12 inches square, and these are secured in brickwork. The strength of the motor depends on the work to be done, in this case being 50 kilowatts. The ropes are of hemp 1 inch in diameter:

centres 20 feet apart. The motor, which is fitted with main and starting switches, runs continually, the ropes being switched in by friction clutch.

Electric Locomotives.—Electric locomotives (Fig. 117), taking their current from overhead trolley wires, are largely employed in America and on the Continent. Like compressed air locomotives, their chief advantage lies in the fact that they accompany the trip, and consequently all the drawbacks incidental to the source of power being at a distance from the

FIG. 117.—Electric Locomotive.

point where it is applied are abolished. Also, where "day-eyes" are used instead of shafts, it is a great advantage to be able to bring the gang right to the surface without changing. Unlike compressed air locomotives, the use of electricity for this purpose is undoubtedly attended by certain dangers, but their introduction into many mines during recent years no doubt signifies that many of these dangers can be avoided.

The two chief advantages of electric locomotives are as follows:

(1) Less cost of maintenance—no ropes, pulleys, rollers, etc., being required.

(2) The loss due to running of rope when little or no load is on the rope is avoided.

Against these must be set great initial cost and liability to accident.

Aerial Ropeways.—In addition to the transmission of power underground by means of ropes, ropeways are used largely on the surface in the form of **aerial ropeways** for transporting material over long, and in many cases, hilly districts. Where a good and efficient system is erected, this means of conveying material is cheap, and the first cost is not as a rule great. Various considerations have to be made in deciding upon the method of transport:

(1) The nature of the country.
(2) The probable extent and inclination of the spans.
(3) The character of the material to be carried and its amount.
(4) The power available for hauling.

The different arrangements of aerial ropeways may be described as follows:

The Endless Rope System.—This system is practically the same as underground Endless Rope Haulage, consisting of an endless rope, carried at a suitable height above the ground by means of pulleys fixed to iron or wooden posts, and driven by an engine, the rope passing round a pulley at the far end, arranged with tightening gear, and returning parallel with the outgoing rope. Carriers are hung on to the rope at intervals, and the rope moves at a slow even speed, say three or four miles per hour, delivering a regular supply of full carriers at one end and bringing back on its return journey a regular supply of empty carriers. The engine is generally similar in type to the ordinary hauling engine with drum 6 to 12 feet in diameter. The posts are erected at intervals of 150 to 400 feet according to the state of the ground over which the ropeway passes, pulleys being fixed at the ends of projecting arms; the posts are made sufficiently high to enable the carriers easily to clear obstacles on the ground. The endless rope system may again be divided into two forms—in one case the carriers are attached to the rope simply by frictional contact, in the other they are firmly secured to the rope by means of a steel band.

(*a*) **Frictional Contact** (Fig. 118).—The carriers are suspended from the rope by a curved hanger, and the upper end of this hanger is attached to an inverted V-shaped saddle resting

on the rope. The weight of the carrier and its load is sufficient, with ordinary gradients, to cause the rope to convey

FIG. 118.—Aerial Ropeway.

carrier and material without any additional connection. Two small wheels are also fitted near the V saddle, and these enable the carrier, when it arrives at either terminus, to be run

FIG. 119.—Aerial Ropeway.

on to the terminal rails or shunts as desired. This system is very suitable for supplying 300 or 400 tons a day on gradients of not more than, say, 1 in 4 or 1 in 5, where the lengths of spans are not greater than the distances already mentioned, and where the carrying capacity of each bucket is not required to be more than 5 cwts.

(*b*) **The Fixed Grip.**—This method (Fig. 119) resembles the last in all features, except the mode of attaching the carrier to the rope. In this case a steel band encircles the rope, formed in such a way that the weight of the carrier tightens its grip upon the rope, in this way resembling a good clip for underground work. This system is suitable for all gradients, and the speed of the rope can be reduced somewhat in this case if required.

The Stationary Rope System.—For heavy weights and continually altering gradients it is necessary sometimes to haul the carriers by means of a rope, using a second stationary rope as a rail. In this case a couple of fixed ropes are suspended from posts, and carriers hanging from them by means of pulleys are pulled to or from the loading and unloading stations by means of a third endless hauling rope. A modification of the pulleys attached to the posts and a special arrangement of hauling rope guides for passing the same have to be made in this case, but apart from these this system is like the others. The disadvantages of these systems are:

(1) That in case of damage to rope owing to wear and tear, it becomes an expensive matter to renew or re-splice.

(2) That it is a difficult matter to arrange for turn-outs or pass-byes where one rope is used.

(3) That the rope is required to be extremely strong and heavy for long distances.

The cost of aerial ropeways varies considerably, but a double-wire ropeway in 300 ft. spans, endless hauling rope, double standards 15 ft. high, with carrying rope saddles, bridge rails and hauling-rope guides, for delivering 30 tons an hour, would probably cost six shillings to eight shillings per yard of double ropeway.

Questions on Chapter IX.

1. Draw a good form of wheel for a mine waggon (tub, hutch or tram); state what it is made of, and show how it is attached to the waggon and how the axle is lubricated. (1901.)

2. What sort and weight of tram rails do you consider the best for underground use, where the loaded tubs weigh 10 cwts.?

3. Describe and sketch a good form of tub, and show how the capacity of the tub is ascertained.

4. What weight of coal would a tub hold of the following dimensions: Length, 3 ft. 8 in.; width, 3 ft. 0 in.; height, 1 ft. 6 in.; specific gravity of coal, 1·3.

5. Sketch a steel sleeper, and show how the rail is made fast to it. How do steel sleepers compare in point of economy with wooden sleepers? (1902.)

6. Describe a good form of tub controller for use at the top of an incline where tubs have to be let down in gangs of 6 or 8 tubs at a time.

7. Describe and sketch two good clips for Endless Rope Haulage.

8. Describe the method of underground haulage by the Endless Rope system, showing how branches are taken off, tubs conducted round curves, fixed to the rope, and also details of the construction of the roads and of the tubs.

9. Describe the Main and Tail rope system of underground haulage, and illustrate your answer with sketches. (Newcastle.)

10. What are the most frequent accidents in haulage, and what precautions would you take in regard to them?

CHAPTER X.

COAL-CUTTING MACHINES.

THE amount of coal obtained by coal-cutting machines is increasing every year, but it is still a very small proportion of the total amount mined. There are many advantages to be derived from the use of these machines, the chief of which are :

(*a*) The most laborious work of the collier is abolished.

(*b*) Coal is saved, the holing being done immediately above or below the coal ; or, if in the coal itself, a small depth of holing is required.

(*c*) The work can be done at any time of the day or night.

(*d*) Very thin seams of coal, considered unprofitable when got by hand, may be worked with profit by machines.

But there are disadvantages in the use of coal cutters also, viz. :

(*a*) They are expensive both to buy and maintain.

(*b*) They need careful watching, as a breakdown means a great loss of output of coal.

(*c*) To obtain the best results a regular face must be maintained, and in many mines this is not an easy matter owing to the character of the roof.

Machines Used.—There are several kinds of machines at present employed for the various operations of different mines or parts of mines. They may be classified as follows :

1. Percussive machines.
2. Rotary disc machines.
3. Revolving bar machines.
4. Chain machines.
5. Heading machines.
6. Shearing machines.

Percussive Machines.—Percussive machines are also referred to as Pick or Puncher Drills and Mechanical Chisels.

There are two distinct forms of these:

(*a*) Wheel machines.
(*b*) Stand machines.

In both these forms an air cylinder with piston is used, but in a **Wheel Machine** the air cylinder is mounted on wheels and moves about in the hands of the operator while the blows are being struck.

In a **Stand Machine** the air cylinder is fixed to a rigid stand, and it is only possible for the operator to vary the direction of the blows: the holing is done by the operator sweeping the machine with its cutter through an arc of a circle and afterwards increasing the length of the cutter arm.

FIG. 120.—Ingersoll Percussive Machine.

Wheel Machines.—The machine is taken to its place at the face on a low truck, and is then run on to a wooden platform (Fig. 120), 3 feet wide and 8 or 9 feet long. The end of this platform nearest the face rests upon the floor, the opposite end being raised 12 or 13 inches by resting it upon a stand. This inclination of the board serves to neutralise the recoil of the machine caused by the striking of the pick. A hose 1 inch diameter and about 50 feet long is then coupled to the machine and also to the compressed air supply, a stop-cock being provided a short distance from the machine. The operator sits behind the machine upon the board, and it is necessary

for him, not only to direct the blow by means of the handles which he holds, but also to control the blow by varying the position and length of stroke according to the hardness of the coal. The harder the coal the longer must be the blow, and this is obtained by drawing the machine further back. Machines deliver from 150 to 250 blows per minute. As much coal is holed as possible while the board is in its first position; afterwards a second holing may be commenced, and the board if necessary lowered so that the pick may strike higher up the coal.

Stand Machines.—These machines are specially adapted for undercutting and nicking the sides in headings. By their aid, headings can be driven rapidly and economically in a manner quite impossible a few years ago. The most common machines are the "**Siskol**," the "**Little Hardy**" and the "**Radialax.**"

Siskol (late "Champion") Coal Cutter.—This machine (Fig. 121) is of the percussive type, worked by compressed air, and consists of five essential parts, namely:

1st. the supporting column, which can be extended by means of a screw in the usual manner;
2nd. the toothed segment;
3rd. the air-drill;
4th. extension rods (five); and
5th. the cutting bit.

It is a machine particularly suitable for headings, pillar and stall work, and for working on a longwall face under certain conditions where it is not advisable to use the ordinary disc or chain type of longwall machine.

The advantages of this machine are:

1st. It is extremely light and portable compared with other types of heading machines. A complete machine weighs between 500 and 600 lbs. according to the height of the supporting column. As the various parts of which it is composed can be disconnected in about five minutes, and, as the heaviest part only weighs 200 lbs., the machine is easily and quickly transported from one place to another, and when working on a longwall face a sledge or trolley can be fitted to the base of the column, thus rendering it unnecessary to dismantle the machine when being removed.

2nd. It can quickly be adapted to all conditions of working, such as holing or cutting at any height, and at any angle between the floor and roof of a seam, shearing or nicking, boring shot holes and wedging. This is due to the fact that the sleeve can be clamped to the column at any height, and by this means it is possible to make a cut at any height between the

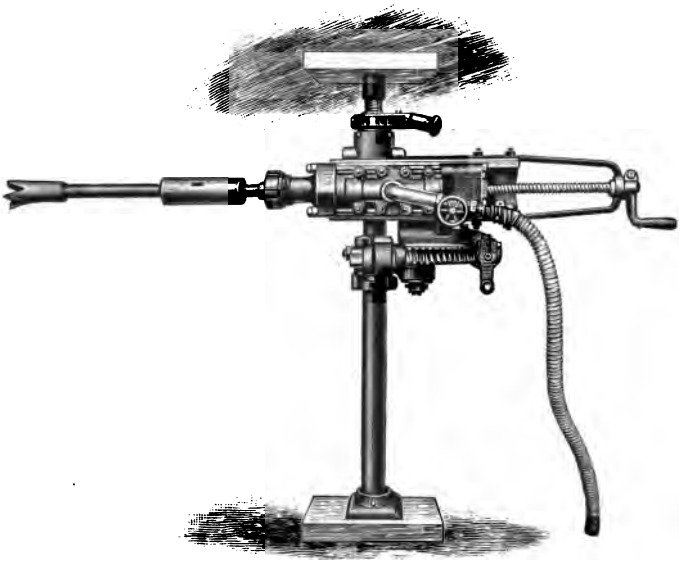


FIG. 121.—"Siskol" Percussive Machine.

floor and the roof by fixing the sleeve on the column at any desired position. The **segment**, which is the part connecting the drill with the sleeve, is so mounted on the sleeve that it can be rocked therein to any desired angle. It is therefore evident that the machine can make a cut, not only at any height, but at any angle, and it is unnecessary therefore to set the column in any particular position to ensure the proposed cut being made in any certain plane. The latter feature of this machine chiefly accounts for its success and for its numerous applications, as without this swivelling point the plane of cutting would be in a

fixed relation to the position of the column. If the swivelling point were not provided, it would necessitate the setting of the column with due regard to the cut to be made ultimately, which, it is evident, is a matter of some difficulty.

When the machine is in position it is handled by one man or a boy. With one hand he turns the handle of the worm, thereby producing a swinging action of the drill, whilst with the other he regulates the advance of the drill into the coal by feeding it forward as in an ordinary rock drill. During work the cutting bit strikes the coal at the rate of about 350 blows per minute. If allowed to strike upon one place only, the cutting bit would soon penetrate into the coal, but whilst at work it is moved by means of the segment, and each blow is, consequently, in close proximity to the preceding one, thereby producing a channel or cut. It describes an arc having for its centre the axis of the segment. The corners of this arc are squared by using larger rods in the corners only, thus making the cuts of uniform depth throughout if necessary. Extension rods of various lengths are used, and as the cut gets deeper the rods are changed for longer ones. In ordinary circumstances the machine cuts to a depth of six or seven feet and up to twenty feet wide at one setting of the machine, although these measurements can be increased by the employment of rods of longer lengths.

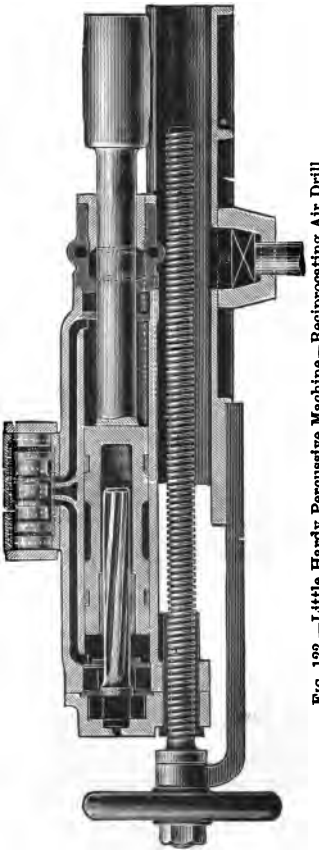


Fig. 122.—Little Hardy Percussive Machine—Reciprocating Air Drill.

The **Little Hardy** machine consists essentially of a reciprocating air-drill (Fig. 122), provided with a cutter arranged to deliver from 500 to 700 blows per minute. The cutter is fixed in position and held up to its work by means of a solid drawn steel tube provided with powerful jack-screw and toothed at head and foot. The machine is seated in a cone cup forming part

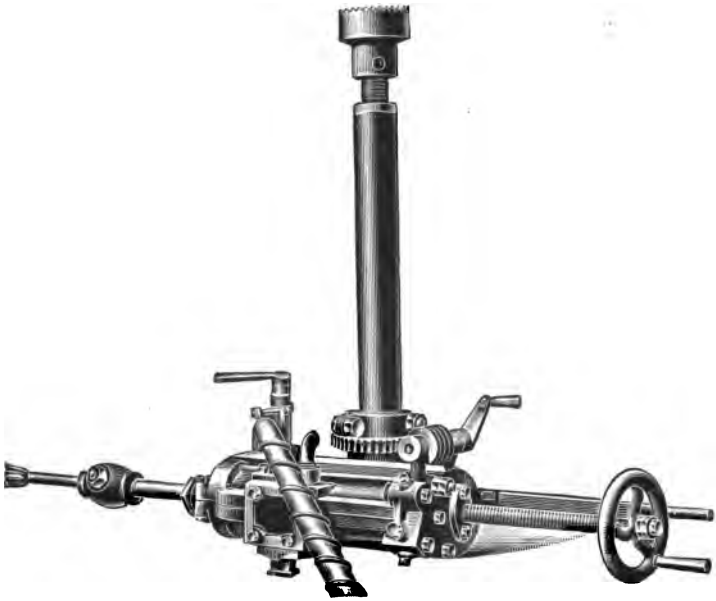


FIG. 123.—Little Hardy Machine, fixed to cut at Floor Level.

of a hinged clamp attached loosely to the column. This clamp carries a worm, the teeth of which engage with those of a worm-wheel bolted rigidly on the column. It is obvious that by turning the worm-handle the coal-cutter is caused to move around the column, whilst the forward movement into the coal is obtained by the feed-screw controlled by the wheel illustrated at the back of the machine. Fig. 123 gives a side view of the complete apparatus fixed for work at floor level, and of course the machine may be fixed to cut at any height between floor and roof.

The friction between the hinged clamp carrying the machine and the column itself may be regulated to a nicety by the operator, relieving the worm of the shock of the recoil without in any way impeding the free movement of the machine right and left across the coal face. When air is admitted to the machine, the rapid and powerful blows quickly cut away the coal or other material, whilst the machine is swung right and left by the worm-gear and is fed forward as necessary. An arc-shaped and continuous channel or undercut is thus made, increasing in depth and width as each successive length of cutter bar is inserted.

As soon as the desired depth is attained at the centre of the working place, the operator commences to play in gradually decreasing sweeps upon the right- and left-hand sides of the arc-shaped cut, using longer cutter-bars where necessary, until the under-cut or channel is of uniform depth at every point, quite square at the sides and corners. When pillars are being taken out, or in working on a longwall face, the successive cuts break into one another, giving a continuous undercut of even depth the whole length of the coal face. Generally, each cut from one fixing is from 15 feet to 20 feet in length by 4 feet to 6 feet deep and about 3 inches in height. The diameter of the cutters is varied to suit different requirements.

If it is desirable to shear (slot or nick) the coal after the undercut is finished, the machine is fixed near the centre of the column, and is worked by a lever from top to bottom. These machines are also made to cut at any angle from a perfectly vertical column by means of a special connection to the stand.

The total over-all length of the machine ready to start, from the extremity of the cutter bar to the end of the swinging lever, is about 4½ feet, and as props may be set at from 2 feet to 3 feet each side of the supporting column, there is no interference with the work.

The Little Diamond is used for the same class of work as the "Siskol" and "Little Hardy," but has the following novel features:

There is no worm and quadrant, the body of the machine being held in a claw shaped swivelling bracket so that the support is in the direct line of the blow, thus reducing the unpleasant vibration common to this class of machine, minimizing wear and tear and enabling the drill to be swung round in any direction and at any angle with the greatest ease. The

valve is very simple in construction, and is actuated by differentiating the air pressure, and being independent of the air passing through the main cylinder cannot stick in the manner common to most machines of this type. Both the drill and bits are detachable and interchangeable.

The machine delivers from 400 to 500 blows per minute with 70 lbs. pressure, and can be used for undercutting, shearing, or drilling with one setting of the pillar and clamp.

Advantages of Pick Machines.—There can be no doubt that for certain kinds of work, the pick machines are peculiarly suitable. It is not claimed that they will undercut as great a length on a longwall face as rotary machines: 80 feet of face holed 5 feet deep in 8 hours is considered good work for one machine; but it would be impossible to apply the latter for headings in pillar and stall work, or for taking out pillars of small size. It is for this kind of work and for longwall faces with irregular and broken seams, that pick machines are best suited. Many instances also occur where it is impossible to arrange the timbering to suit a rotary machine. The pick machine will work around the props and sprags; consequently there need be little alteration of these. Again, it may be impossible to keep goaves well back, the space at the face may thus be limited, and a large cutter would be impossible. Where the coal contains hard impurities and bands, these can be more easily avoided by pick than by disc machines.

Rotary Disc Machines for Longwall.—Many longwall machines of the disc or circular saw type are at present in use, the majority being driven by compressed air although a large number of electrically-driven machines are now in use in those mines where electricity is installed.

Mode of Working.—All longwall machines are self-propelling, being provided with a small drum on which a rope which passes round a post some distance along the face is wound, coiling on the drum when the machine is at work. The knives or cutters are arranged on the periphery of the wheel (Fig. 124), cutting into the coal as the wheel revolves and the machine moves slowly along the face.

The machine may run (*a*) upon one or two rails, (*b*) upon skids or sledges, (*c*) upon the hard floor of the mine.

In the case of rails, side-thrust is prevented by means of special sleepers and light screwjacks. In other circumstances

the machine is kept up to its work by means of a row of props—placed on the goaf side of the machine—which press against a plate of sufficient length, attached to the machine. In most cases the cutting wheel clears itself as it rotates, and may be arranged to cut at the *bottom* of the seam, at the *top* of the seam, or *midway* in the seam, as required. As a rule the wheel

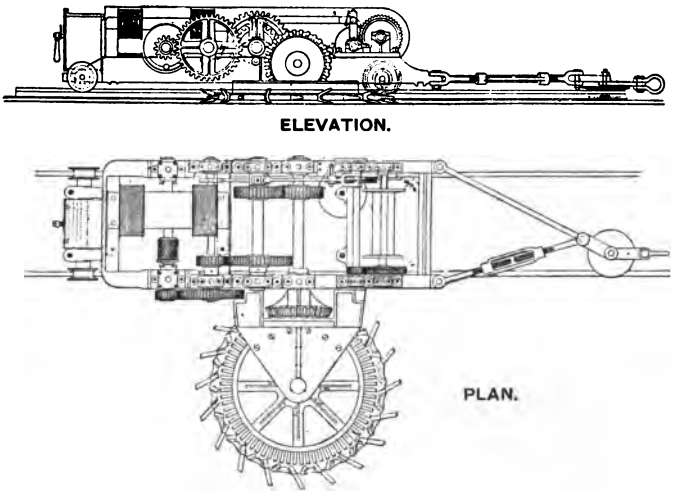


FIG. 124.—Electric Longwall Coal Cutter—Disc Type.
[*Reproduced by permission of the Institution of Mining Engineers.*]

may be tilted slightly up or down so that obstacles occurring in the coal may be ridden over, or loosened, or the irregularities of an uneven floor may be followed.

It will thus be seen that when power is applied, all its actions are automatic; the coiling of the rope upon the drum, which causes the machine to move along the face, being controlled by the rate at which the wheel cuts. The form of cutter-knives varies in different machines. They may be either straight or curved, and are always interchangeable.

Construction of Machine.—The general construction and working of the machine is very similar whether driven by electricity or by compressed air, a small motor in one case taking the place of the air cylinders and pistons of the other.

In an Electric Coal Cutter, a motor of 20 or 25 H.P. is provided, attached to which is an enclosed starting switch connected to a trailing cable. The switch is generally at the rear end of the machine, as in Fig. 124. On the armature shaft is fixed a geared wheel, but as its speed would be too great for the cutting wheel it is geared down to a suitable speed by other geared wheels. On the upper side of the disc, teeth are formed which are engaged by those of a vertical bevelled wheel as shown.

The speed at which the machine advances is controlled by an eccentric at the side of the machine, operating through a ratchet and pawl arrangement on the haulage drum.

FIG. 125.—Standard Diamond Electric Longwall Machine—Undercut Type.

Most electric cutters are driven by continuous current, but recently alternating current machines have been introduced, their great advantage being that they need no commutators or brushes; consequently they are not liable to give off sparks.

In a Compressed Air Coal Cutter, two small cylinders are used, of 9 or 10 in. diameter and about 9 in. stroke, and placed either side by side or at each end of the machine; and to these cylinders are connected flexible hose pipes provided with stop-cocks for admitting the air. The speed of the shaft driven by the pistons of these cylinders is not so great as is the case with electricity, and consequently it is not necessary to bring about so great a reduction in speed. In other respects the mechanism of a compressed air machine is very similar to an electrical one.

Coal Cutters are arranged to undercut to various depths from 2 ft. to 7 or 8 ft. The height of the undercut also varies

FIG. 126.—Underground Photograph of Diamond Longwall Machine at fast end of Face, commencing to cut its own way under coal.

FIG. 127.—Diamond Coal Cutter; Photograph of Machine after cutting its own way into Coal at fast end.

from about 3 to 5 inches. The usual height of a coal cutter mounted on the rails is about 22 inches, though machines for

thin seams are made as low as 16 inches. They are generally about 3 feet wide and 5 to 7 feet in length.

The most common Coal Cutters of this type at present in use are : the **Jeffrey, Diamond, Gillot and Copley,** and **Clarke Stevenson.**

The Revolving Bar Machine.—In revolving bar machines, a revolving bar is substituted for the circular disc of the rotary machines. This bar standing out at right angles to the machine has cutters upon it, and these cut the coal as the bar revolves ;

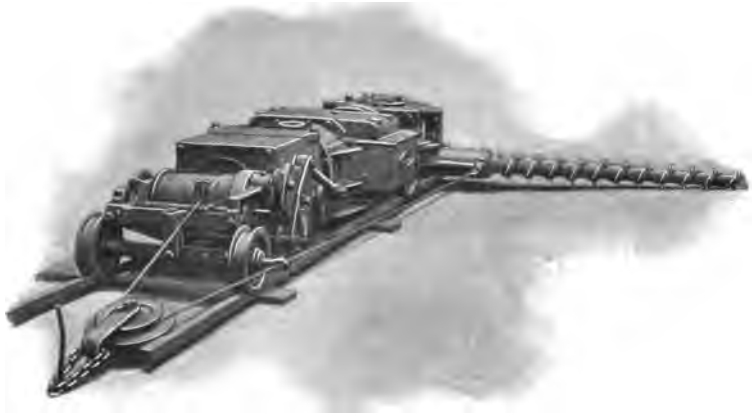


Fig. 128.—The Hurd Bar Cutter, running on Rails.

the clearing of the chippings is accomplished by a slight backwards-and-forwards movement of the bar. The bar is tapered and has a spiral thread formed upon it ; steel cutters are fixed along the bar, on or between the threads according to the height of holing required. The length of the bar is determined by the depth of holing required. As already stated, a reciprocating movement is introduced in addition to the rotary movement, and this gives a combined chipping and shearing action on the coal which reduces the strain in the machine and prevents the cutter bar from clogging. When at work the bar is necessarily close to the solid coal, and then there is little chance of its being jammed by coal coming down, a frequent cause of trouble where disc machines are used. As it is usual to work with the bar

at the back of the machine, there is only slight interference with the work of cutting in case a fall of coal occurs. The bar with its gearing is carried in a turn-table in such a manner that it may be swung in and out of the holing, or tilted up and down when at work, thus forming what is termed a **universal cutting end.** By this means, cutting may be done on either side of the machine, and it will cut into the face without the necessity of making a cut by hand holing. It is an easy matter to fix the bar so as to cut at the top of, or midway in a seam.

In construction the machines are very similar to the electrically-driven disc machines, but it is not necessary to reduce the speed so much in the case of a bar as with a disc. In this

FIG. 129.—The Pickquick Electric Bar Cutter, running on Sleds.

respect the machines are more efficient than those previously described. The most common machines of this type are the **Hurd** (Fig. 128) and the **Pickquick** (Fig. 129).

Chain Machines.—In machines of this type, a revolving chain, with cutters attached, is substituted for the disc or bar of the other types. An American machine, the Morgan-Gardner, was among the first to be employed, but this is now out of use. The **Alliance**, the **Diamond**, and the **Hopkinson** machines are representative of this class.

The Diamond Chain Machine.—The Diamond Company have recently introduced for use in tender coal seams two distinct types of longwall chain coal cutters driven by compressed air and electricity. The centre jib type is designed specially for cutting backwards and forwards without the necessity of turning the machine round. The jib is fixed and the holing dirt is carried by the cutters underneath the machine and cast into the gob. The swinging jib type cuts its own way into the

coal, and as with all machines of this type it is advisable to turn it round at each end of the face or to flit it. The special feature of the Diamond chain machine is that no rivets are used in the chain, and a new link can be inserted in a few moments. One of these machines has been working in a thin seam since 1904, and has averaged nearly 100 yards per shift, holing to a depth of 4½ feet at floor level.

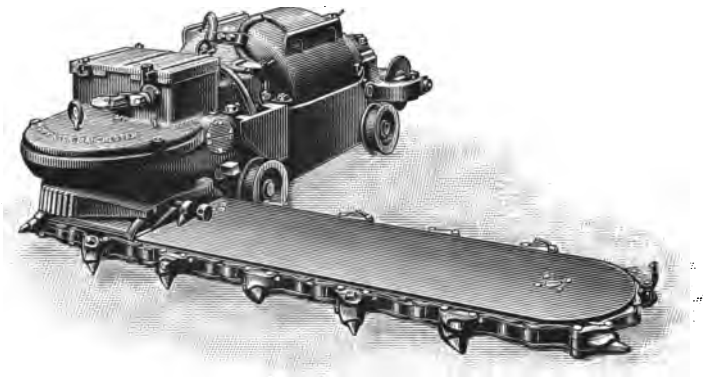


FIG. 130.—The Hopkinson Electric Chain Cutter.

The Hopkinson Longwall Coal Cutter.—This machine (Fig. 130) was put upon the market at the beginning of 1905, and a number are now at work in various collieries in this country. The chief objects obtained by this design are briefly:

(1) Complete clearing of the undercutting from debris.

(2) Capability of cutting into the coal at the beginning of the face.

(3) Small overall dimensions (particularly width) and weight, combined with a powerful motor.

(4) Complete protection of all vital parts ensuring immunity from damage and thorough lubrication, ensuring silent working.

(5) Capacity of being worked without skilled labour.

The machines are made in two sizes for continuous current, and two sizes for alternating current, as in following table. The compressed air machine is arranged in such a way that two or four cylinders can be used, the latter number being employed in cases where the air pressure is abnormally low or the holing very hard. Each type of machine can be adapted for cutting on wheels or on skids and for undercutting or overcutting. The feed gear is usually set for a speed of from one to two feet per minute, and the machine cuts its way into the coal in between 5 and 10 minutes. In ordinary fireclay holing of medium hardness seven to twelve electrical horse power are absorbed on the average, when cutting to a depth of four feet at about eighteen inches a minute.

FIG. 131.—Hopkinson Chain and Tool Holders.

SIZES OF MACHINES.

	Length.	Width.	Height on Skids.	Height on Wheels.	Max. Undercut.	Weight.
CONTINUOUS-CURRENT MACHINES.						
No. 1,	8′ 2″	26″	26″	27″	6′ 6″	43 cwts.
No. 2,	6′ 6″	22″	22″	23″	4′ 9″	23 cwts.
ALTERNATING-CURRENT MACHINES.						
No. 3,	8′ 2″	27″	27″	28″	6′ 6″	42 cwts.
No. 5,	6′ 6″	23″	23″	24″	4′ 9″	22 cwts.
COMPRESSED-AIR MACHINE.						
No. 4,	6′ 3″	24″	17″	18″	4′ 6″	21 cwts.

The Alliance is an American machine of the swinging jib type, but there are at present few of them at work in this country.

Heading Machines.—The **Heading Machine** makes its cut straight to the front. The principal parts are: first, the bed frame, which is the stationary part, secured both back and front to the face and roof by jacks; second, the sliding-chain cutter frame which, as its name implies, slides on the bed frame and carries the revolving chain on which the knives are fixed; third, the motor carriage, to which the motor and gearing are fixed, and which is attached to the sliding frame.

FIG. 132.

The **Mode of Working** is essentially different from that of a longwall machine. Mounted on a truck which runs on the ordinary rails, the machine is hauled to the face of the heading and there run off by lifting the rear of the truck. It is next secured in position by the jacks and the cable coupled up. The cutter frame advances as the chain revolves, the operator being at the back of the machine while it is cutting. The gearing is then reversed, and the cutter frame travels back to its first position. By means of crowbars the machine is moved into position for the next cut, and so on until the whole width of the heading has been cut, after which it may be hauled on to the truck and taken to the next stall.

Shearing Machines.—**Shearing** or **Slotting Machines** for cutting at the fast side in headings and other purposes are now often used, though the work is also done, as has been explained, by percussive cutters like the Siskol and the Little Hardy. The action of a shearing machine is entirely different from the action of a percussive machine.

A Shearing Machine such as the **Jeffrey** (Fig. 133) consists of three parts: (1) the bed frame; (2) the sliding cutter frame; (3) the motor carriage. The cutter frame, as in the case of a Heading Machine, carrying an endless chain on which are fixed the knives, moves slowly forward upon the bed frame as the chain cuts its way into the coal. The driving power may be either an electric current or compressed air.

FIG. 133.—Jeffrey Shearing Machine.

The **Mode of Working** is as follows: The machine is placed in position on the floor at the face; the jacks—of which there are four—are screwed tight, and the machine raised to cut the top of the seam. A cut 3 feet high, 7 feet deep, and 4 inches wide is now cut into the coal, after which the machine is lowered the distance equal to the cut, viz., 3 feet, and is then ready for making a second cut similar to the last. This process is continued to the bottom of the seam, the operation lasting probably 30 minutes in the case of a 7-feet seam.

Questions on Chapter X.

1. What are the most important coal-cutting machines? Classify them according to the nature of the cutting appliances. (1901.)

2. Describe one of the coal-cutting machines of the Percussive type, either wheel or stand machine.

3. What advantages are claimed for Percussive Machines?

4. What principles have been adopted in the design of Longwall coal-cutting machines? Describe the construction and use of one form. (1898.)

5. Describe some form of coal-cutting machine, giving details of the method of driving, arrangement of the working staff and other details incidental to its use. (1897.)

6. Describe a Revolving Bar coal cutter, and state its advantages and disadvantages.

7. What conditions are most suitable for the application of coal-cutting machinery? What advantages attend their use, and what are the chief difficulties likely to be met with?

8. What are the main parts of a heading or shearing machine? Compare the mode of action of a heading machine with a stand percussive machine in driving headings.

9. What considerations would guide the colliery manager in determining the position of the holing when using mechanical coal cutters?

10. What are the dangers incidental to the use of mechanical cutters in coal mines?

CHAPTER XI.

WINDING.

THE winding of the coal from the bottom of the shaft of the mine to the surface, together with the lowering and raising of workmen and materials, is done by means of cages suspended on a rope, which is wound upon the drum of a stationary engine. In a modern colliery, the winding is done very rapidly, but nevertheless with perfect safety. For this purpose an **engine, ropes, cages,** and **rods** are necessary; **receivers** are fixed at the surface to steady the cage; **keps** or **catches** are used at the top and bottom of the shaft on which the cage may rest; **detaching hooks** are employed to prevent accidents in the case of overwinding; and large **headgears** are also fixed to support the pulleys over which the ropes pass from the cages to the drum of the engine. It is thus seen that the equipment of a colliery shaft is a costly and serious matter, and the maintenance of the whole of the arrangements in perfect working order is one of the most important duties of the mining engineer. It must also be remembered that, in addition to the arrangements described, the shaft equipment includes pipes for conveying steam, water or compressed air; cables for transmitting the electric current; ropes for underground haulage; and signalling wires for communicating from the surface to the workings.

Cages.—Cages are now made with one, two, or even three decks, and capable of holding one, two or three tubs in each deck. They are formed generally of rolled steel with sides and floor of sheet-iron—though sometimes wood planks are used for the latter. The top of the cage is sometimes flat, but generally consists of inclined iron plates or a semi-circular

bonnet (Fig. 134), forming a roof and a protection for persons riding in the cages.

Rails are laid on the floor of the cage for the tubs; thus, in loading and unloading, the tubs in the cage are easily pushed out by the incoming ones. When wire-rope rods or

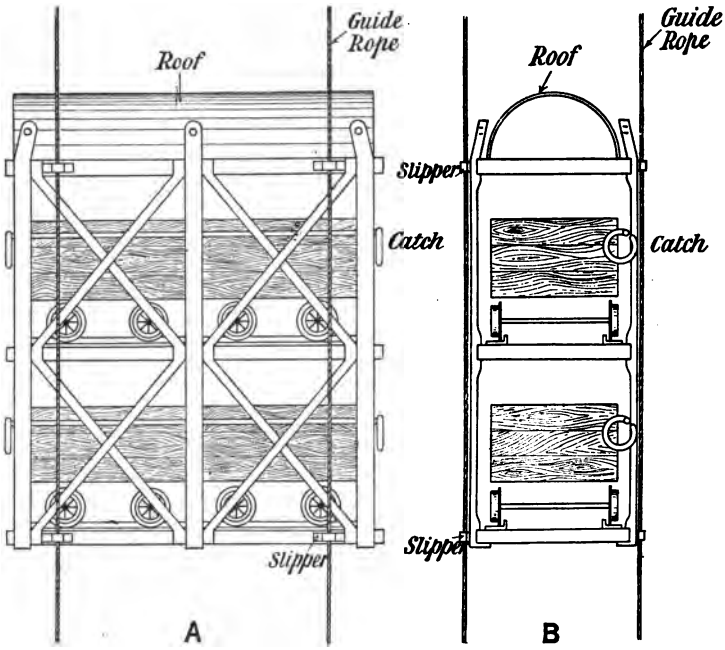


FIG. 134.—Double-decked Cage used for Winding.

conductors are used, **thimbles** or **slippers** are fixed at suitable points on the outside of the cage, through which the conductors pass, thus holding the cage steady as it passes up and down the shaft. As a rule these conductors or **guides** are placed two on each side of the cage.

The weight of the cage, which of course will be regulated by the strength of the material, should not be greater than is necessary to carry a certain weight, but, with the greater strength

of modern winding engines, it is now possible to have an absolutely strong and safe cage without danger of overweight.

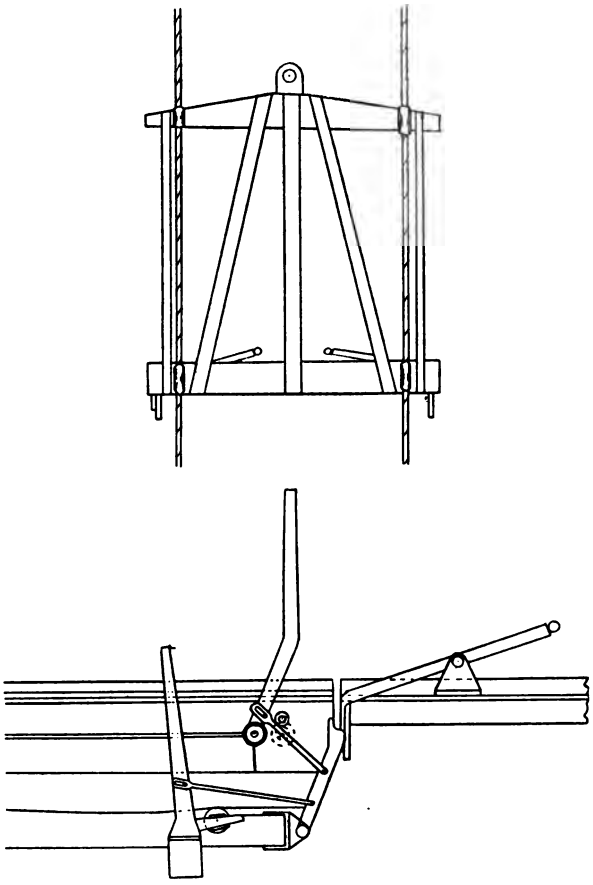


FIG. 135.—Automatic Catches.

The weight will vary according to construction, a convenient weight being $1\frac{1}{4}$ tons for a two-decked cage, carrying two tubs in each deck.

Catches.—To keep the tubs in the cage during winding, a catch is necessary. This catch may be placed either at the side of the cage (Fig. 134) or above the tubs. The simplest and handiest form is that in which an iron bar runs from end to end of the cage and terminates in a circular end at right angles to the bar (Fig. 134). This bar is thrown over to the right or left as required, to admit of the tubs being pushed in or out, and thrown back again when the tubs are in, to prevent them coming out.

Automatic Catches.—Catches placed on the floor of the cage (Fig. 135), and consisting of heavy bars of iron running parallel with the rails, are used where automatic keps are employed. The bars are supported in such a way that when the heavier end is down, the raised portion is just the height of the axle of the tub. It will be seen that the tubs can be run in from each side of the cage, but will be prevented from getting out again by the axles coming in contact with the ends of the bars. Here the tubs are securely held until the cage arrives at the top or bottom. In addition to the ordinary keps upon which the cage rests, other keps are provided which are brought into operation when the cage arrives at the top or bottom. A plate supports the under side of the bars, and, as the cage is lowered on to the keps, a projection, connected to the hand lever shown in the illustration, supports and raises the plate. The end of the bar in the cage is lowered, whereupon the tubs pass out of the cage, either of themselves or by the aid of the banksman. A small lever placed between the rails near the pit top is caught by the axle of the tub as it passes, and this draws the extra keps from under the plate, which, together with the bars, immediately resumes its proper position and prevents further tubs from passing out. When the ordinary keps are afterwards withdrawn, the cage is free to pass.

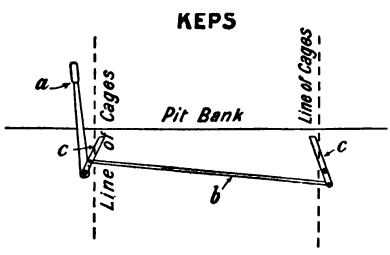


FIG. 136.—Keps for supporting Cage during Loading and Unloading.

Keps.—Keps are used for the purpose of supporting the cage at the top of the shaft, while it is being loaded or

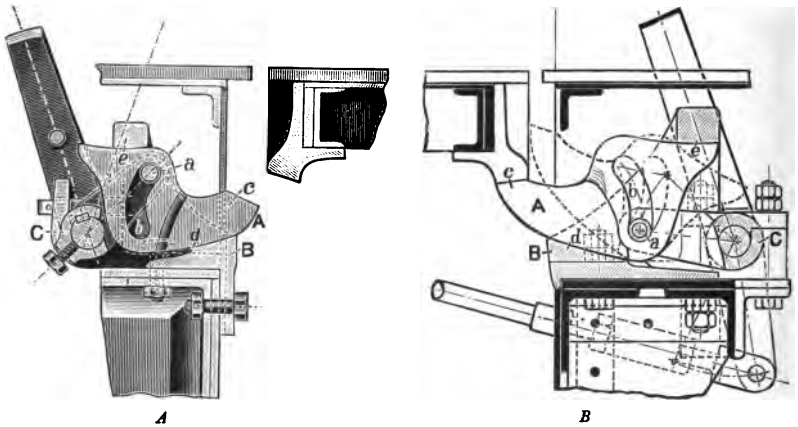
unloaded. A simple arrangement is shown in Fig. 136. A lever *a* actuates the connecting rod *b*, which is eccentrically fixed to carriages *c*, *c*. By one movement of the lever, the latter can be moved into position under the cage or withdrawn therefrom as required.

Beien's Keps.—The latest contrivances and improvements of props and keps are formed so as to allow the descending of the cage in the winding shaft without the necessity of previously raising the cage by mechanical power. The great advantages gained by these new keps compared with the other forms are: Lessening of labour in manipulating the winding engine, and also in banking; complete absence of shocks, which are unavoidable with the ordinary keps; prolongation of the life of winding engine and gear; saving of steam and time, and therefore great increase in winding efficiency; and reduction of wear and tear on the whole of the winding appliances.

Beien's Keps constructed on this principle have now been in use for many years, and have proved very successful. They are adopted by many collieries on the Continent, where their advantages have long been recognised. Most keps have a large number of pins and working parts through which the shock of the cage is transmitted, thus causing them to wear rapidly. Again, where the shoes of the cage are angled to a great extent (sometimes as much as 45%), a great outward strain is put upon the kep joists. In the Beien system, owing to the ingenious nature of its construction, the working part and the pressure on the same are reduced to a minimum, and the outward strain of the kep joist is avoided to the greatest possible extent.

The following is a complete description of this patent kep arrangement (Fig. 137). The essential parts are: A free supporting bar (*A*), the casing (*B*), the twin or forked lever (*C*). The latter is keyed on the shaft of the supporting bar (*A*), and makes with it a circular movement. The shaft has strong bearings in the casing (*B*). The connection of the twin lever (*C*) with the supporting bar (*A*) is effected through a pin (*a*), which bears a roller, and is caused to move in a circular slot (*b*) in the bar (*A*), whereby the bar executes a backward or forward motion. The winding cage rests on an inclined surface (*c*) on the bar (*A*). The pressure exerted by the winding cage on the bar (*A*) is taken by the surfaces (*d* and *e*) on the casing (*B*). Both surfaces (*d* and *e*) form in the vertical elevation a part of

the circumference of two concentric circles. The middle tangent of the contact surfaces (*d* and *e*) forms an acute angle, which corresponds with the friction angle, and thereby the pressure against the pin (*a*) is reduced to a minimum. The bolt (*A*) when withdrawn executes not only a backward but also a downward motion, on account of the concentric surfaces of the bar (*A*) and the casing (*B*), whereby the winding cage receives a slowly downward movement. In case it should happen that the bar (*A*) is pushed forward too soon, before the



A *B*

FIG. 137.—Beien's Keps.

winding cage has reached the proper height, the ascending cage will turn the bolt (*A*) round the pin (*a*), whereby the bar (*A*) is reached in a position as shown by the dotted lines in Fig. 137 *B*, and the cage can pass freely through. After the cage has passed the bar, the latter again falls into its original or operating position, by reason of its own weight, and is ready for the cage to rest upon.

Fig. 137 *A* shows the withdrawn supporting bar in position so as to allow the cage to be lowered down the shaft. For light winding cages it is sufficient that the frame of the cage rests directly upon the supporting bars (*A*), they having very broad wearing surfaces. For heavy winding cages, special counter shoes with corresponding obliquity to the supporting bars, and

riveted firmly on the under frame of the cage, are preferable. The parts are exceedingly strong, and a load of 27 tons can be carried on the keps.

Reumaux Keps.—At the Lens Collieries two-decked cages are used with four tubs to each deck. Keps are provided acting like ordinary ones, but they may also be drawn from under the cage without the latter being raised. This is a great improvement, the strain on the engine and rope, and the extra time employed where ordinary keps are used, being considerable. The keps are connected to the wire of the underground signal, so that they are withdrawn from beneath the cage by the hooker-on at the bottom of the shaft when he signals to the engineer.

Simultaneous Loading.—Where cages with two decks are used, special arrangements have sometimes to be made. The operation of altering the position of the cage by the winding engine, after one deck has been changed, takes up a great deal of time, besides being somewhat of a strain on both engine and rope. The usual arrangement is to have two platforms, one above the other, on to which the tubs of both decks can be simultaneously run in or out. This plan necessitates twice the number of men, and it is also necessary to bring the tubs up or down from the stages to the same level. It is for this purpose that extra cages with hydraulic rams are sometimes used. Instead of extra staging, auxiliary cages are used having the same number of decks as the winding cages. The tubs are run into these, and while the other cages are moving in the shaft, the auxiliary cages are raised or lowered by hydraulic rams, being unloaded and loaded simultaneously at the top and bottom.

Receivers.—At the top and bottom of the shaft, it is necessary to arrange for the cages to be received between guides of wood, through which the wire rope guides pass. The method adopted will be seen clearly from Fig. 138. *d*, *d*, are the two cages ; *a*, *a*, are the receiving rods, placed two on each side of the cage on each side of the pit. The guide ropes *b* pass through the receivers upward to the beams of the headgear.

Ropes.—Ropes vary not only in regard to size and shape, but in their quality and strength. They are as a rule made round ; flat ropes are expensive and unsuitable for most mining operations. Ropes are generally made of **steel wire**, the quality

of the steel employed being determined by the purpose for which they are required. While it is necessary in the case of a winding rope to have as great a breaking strain per square inch as possible, this is not the only point to be considered ; it will also be necessary to employ material which will best suit the conditions under which the rope will have to work. For small pulleys and drums, a crucible steel-wire rope may be more suitable than the stronger qualities of steel, and would certainly last longer for haulage purposes, where the conditions are better suited to it than a stronger one.

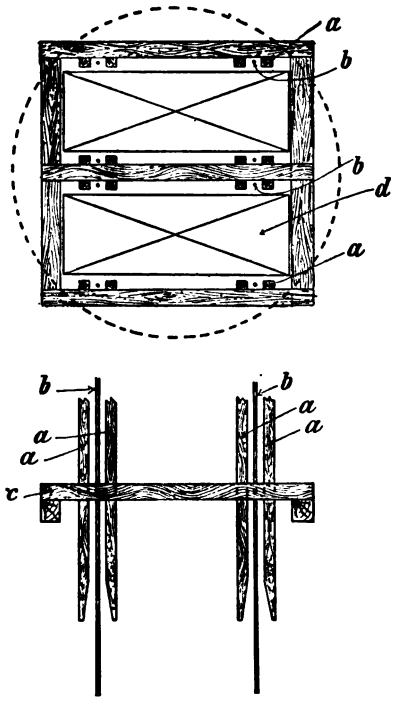


FIG. 138.—Receivers for Cage at Top of Shaft.

As a rule, round wire ropes are made by twisting six strands around a core of hemp or wire. Each of these strands is made up of a certain number of single wires, usually seven, twisted also around a central core of hemp or wire. Fig. 139 *C* shows a rope made in this way of six strands, with a wire core in each strand. The rope may be made also by six strands, each formed of two layers of wires twisted around a central core of hemp, as in Fig. 139 *B* ; this arrangement forms an extra flexible steel wire rope made of six strands, each of 24 wires ; or it may be formed as in Fig. 139 *A* with a wire core in each strand around a central core of hemp. In forming the rope, makers adopt either the method known as **Ordinary Lay** or that of **Lang's Lay**.

In Ordinary Lay, the wires forming the strand are twisted around each other, or round their core in a direction *opposite* to that in which the strands are twisted to form the rope.

In Lang's Lay the wires forming each strand are twisted in the *same* direction as the strands are twisted. By this means a greater area of each strand comes in contact with the

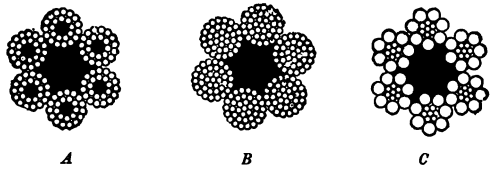


FIG. 139.—Sections of Wire Ropes.

pulleys or wheels, and thus distributes the rubbing. The result is that the Lang's Lay ropes wear well, and wires are not easily broken until the whole of the rope has become thinned through continual friction.

Again, in order to *flatten the strands* and thus render them less liable to unequal wearing, a *triangular solid core* may be used in each strand. Recently makers of ropes have obtained more perfect flattening of the strands by using *oval-shaped cores.*

The weight and breaking strain of a rope will, of course, depend upon the number of strands and the number of wires in each strand, and for this reason it is difficult to calculate their strengths from any given formula. The strength of ropes can only be given accurately by using a formula which will take into account the number and quality of the wires, the number of strands, the nature of the cores and the method of forming the rope. This is almost impossible. The following method is given as an easy means of determining *approximately* the weight, breaking strain and safe working load of various ropes:

C = Circumference in inches (diameter × 3·1416).
W = Weight of rope per fathom in lbs.
B.S. = Breaking Strain in Tons.
S.W.L. = Safe Working Load.
Then C^2 = Weight in lbs. per fathom.

Also $W \times 4 = B.S.$ in tons for Extra Plough Steel.
$W \times 3{\cdot}5 = B.S.$ for Mild Plough Steel.
$W \times 3 = B.S.$ for Patent Steel.
$W \times 3 = B.S.$ for Crucible Steel.
$W \times 1{\cdot}5 = B.S.$ for Bessemer Steel.

Also $\frac{B.S.}{10} = S.W.L.$ for Winding Ropes.

$\frac{B.S.}{6} = S.W.L.$ for Hauling Ropes.

Locked Coil Ropes.—The method of forming this kind of rope differs from all others. The central core consists of a strand of wires twisted together in the usual way. This core is covered by a layer of wires placed side by side, fitting closely together on account of their regular shape (Fig. 140) and forming a complete circle of wires round the inner core. On the top of this layer of wires, but running in the opposite direction around them, is a second layer similar to the last and forming also a complete circle of wires. There may be three or more of these layers running alternately in opposite directions. The outer one, however, differs from the others. Each wire is shaped like the letter S, and consequently one wire fits closely into the other, forming a locked coil, which gives the name to the rope. Locked coil ropes are heavier, stronger and far more expensive than ordinary ropes. Their great merit is that they form practically a solid rod when hung in the shaft, the tendency of one layer of wires to turn or twist being neutralised by the next layer, the tendency of which is in the opposite direction. They are now often used for winding, especially in sinking pits, where they enable an unguided hoppet to be wound up and down without twisting round in the shaft.

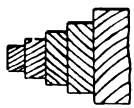


FIG. 140.—Locked Coil Rope.

Examination of Ropes.—The Coal Mines Regulation Act requires that a responsible person shall, once at least in every twenty-four hours, carefully inspect the ropes and other apparatus used for raising and lowering the cages, and that he shall stop the winding of men and materials until the defect has been put right in case he finds any defect or weakness likely to produce danger. This procedure is not sufficient, however, in order to be on the safe side. Many weaknesses do not appear until too late

to be remedied. It is the custom at some mines to assume that the rope will last a certain number of years; the rope will be run for this length of time with little or no examination beyond that specified. When it has run its time it will be taken off and a new one put on. This is a wrong method to adopt. A false security is assumed, while on the other hand it is possible that the rope might last much longer with absolute safety if proper attention was continually bestowed upon it. The following are directions for preserving ropes during their storing, their uncoiling and the period of working.

The ropes should be carefully stored in a room provided for the purpose, and placed on planks raised from the ground so as to be free from damp. Here they should be kept packed in their wrappings, covered with tarpaulin and regularly inspected. When ready for putting on they should be placed on a reel or turntable and unwound from the outer end, the reel being placed on the opposite side of the pulley to the engine. The outer end is then carried over the pulley and coiled upon the drum without danger of kinking. When the rope is on, and in addition to the ordinary inspection, the following precautions should be observed:

1. Jerking at starting should be avoided, as the greatest strain is upon the rope at the moment of starting.

2. Ropes should not be overloaded, and the limit of one-tenth or one-sixth of the breaking strain should never be exceeded.

3. Ropes should not be changed from one drum to a smaller one, and seldom changed from a small to a larger drum.

4. Guide ropes should be carefully weighted below the landing at the shaft bottom and the weights examined regularly.

5. All ropes should be regularly cleaned and afterwards well greased to prevent corrosion.

6. Hauling ropes should be prevented from dragging on the floor or rubbing against the sides of the roads, and they should not be taken round pulleys of insufficient diameter.

7. The regular re-capping of the rope is important, and will be referred to again.

Wire Rope Attachments.—The end of a wire rope is capped so that it can be easily attached to the load. Different

methods of doing this are adopted, the operation being known as **capping**. It is generally necessary to separate and turn the wires of the rope back upon themselves. This, although it is the usual plan, cannot be said to be a good one. The bending of the wires must necessarily weaken them, and, although the socket is placed round the bent wires and secured by stout rings of iron (Fig. 141), its grip almost entirely depends upon the clasp of the cap upon the rope. In some cases a conical wedge is used, and the wires carefully turned back upon this and secured by cap and rings in the same way as the last, or by bolts (Fig. 142 *B*). A much better mode of capping or **socketing** a rope is that adopted at some

FIG. 141.—Wire Rope Capping.

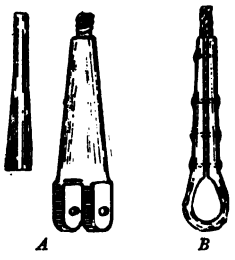


FIG. 142.—Wire Rope Cappings.

mines of filling in the end of the rope with white metal after threading it through the socket, which is a hollow cone of iron (Fig. 142 *A*). About nine inches of the ends of the wires are carefully opened out by means of various sizes of prickers, and white metal run in to fill the cone formed. This metal forms when hard a solid wedge, which can only be got out by melting, and when the socket is fitted over, forms a most trustworthy capping.

Detaching Hooks.—Overwinding is possible even with the most careful engineman, unless an automatic contrivance is used which stops the engine. But it is possible to prevent great damage being done by the cage being pulled into the pulleys in case of an overwind. This is done by means of a **detaching hook**. This hook, which is fitted between the capping of the rope and the cage chains, goes up and down continually with the rope, and is so made that in case the cage is pulled up to the top of the head-gear, the rope is

detached and the cage held, by means also of the hook, in the headgear. Some detaching hooks, however, do not also hold the cage, and it is necessary to employ safety catches in conjunction which will prevent the fall of the cage into the shaft after the rope is detached. The following detaching hooks not only detach the rope, but suspend the cage:

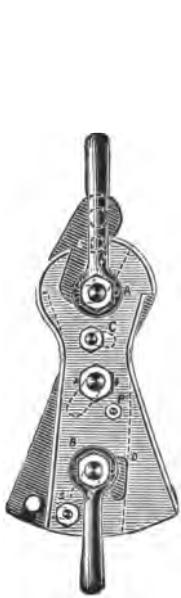


FIG. 143.

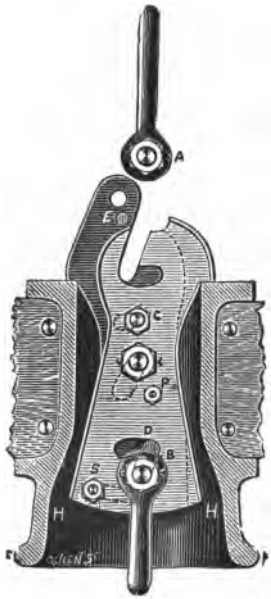


FIG. 144.

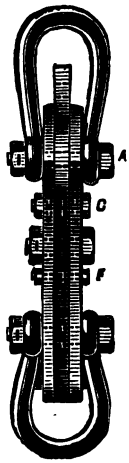


FIG. 145

Ormerod's Safety Detaching Hook.

Ormerod's Safety Hook.—Where a detaching hook is used it is necessary also to fix a thimble or socket in the headgear frame through which the rope is always passing, and into which the hook passes in case of an overwind. This is shaped differently for the various hooks; in the case of Ormerod's hook it is shaped as shown (Figs. 143-5). The hook itself consists of two fixed plates with a third movable plate between them. When the rope *A* is attached, the upper end is closed

over it, and a small copper rivet at *P* prevents the movement of the inner plate during ordinary working. The lower part of the inner plate projects in such a way that it cannot pass through the collar. When the hook is drawn into the collar, the upper portion passes through the narrow neck, but the lower portion is pressed in so vigorously that the copper rivet is cut through. The bolt *I* acts as a pivot, and when the projecting portion is forced in, an opening is made, which

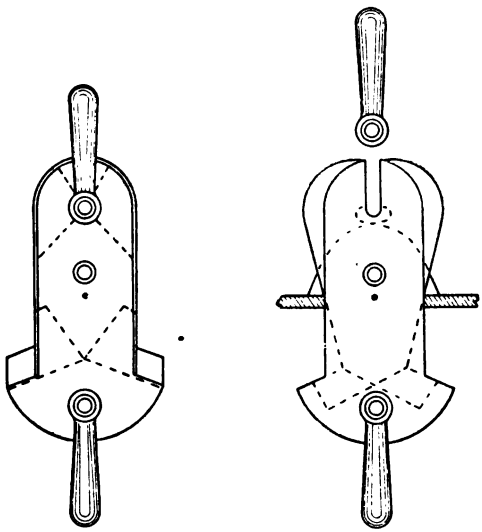


FIG. 146.—King's Safety Hook.

releases the shackle, *A*, of the rope. At the same moment the side arms *E* come into operation and prevent the passage of the hook back again through the collar. The hook with cage is thus suspended. At the same time the shackle *B* has dropped into position at *D*, and practically locks the hook, as it is impossible for the projecting arms *EE* to be contracted until the weight of the cage is relieved and the shackle *B* lifted to its original position. This is done after the rope has been securely fastened once more to the cage chains.

King's Hook.—This hook, shown in Fig. 146, is similar in many respects to Ormerod's, having two plates which overlap, connected to each other by two other plates, the whole being pierced near the centre by means of a pin upon which the inner plate can turn. The width of the hook is uniform except near the bottom, where two projections are fixed, which come in contact with the collar in the headgear in case of overwinding. A copper rivet keeps the plates in position and prevents the shackle from coming out in ordinary circumstances. In case of overwinding, the projecting parts are pressed inwards. This arrangement enables the shackle to be released, and it also causes the upper arms to project so that they cannot pass again through the fixed collar until desired.

Walker's Hook (Fig. 147).—This hook is made in a different form from that last-described. A flat steel plate (*C*) takes the

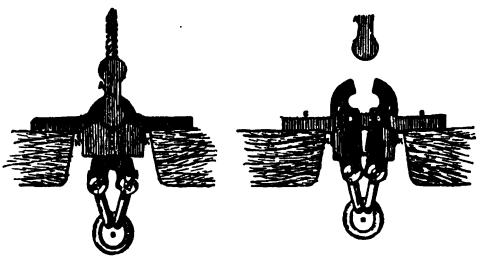


FIG. 147.—Walker's Safety Hook.

place of the fixed collar, and two jaws (*FF*) take the place of the flat plates. The shackle is held by the jaws *FF*, the latter being kept in position by the steel clamp *K*, which, in case of an overwind, comes in contact with the underside of plate *C* and is pressed down upon the lower limbs of the hook, causing the upper limbs to be opened. This releases the shackle, and the points at *FF* overlap the plate, the hook being locked in position owing to the steel clamp *K* being pressed securely down.

Reumaux Obturating Valve.—A safety arrangement adopted at the Lens Collieries, and devised by M. Reumaux, acts as follows: An obturating valve (*i.e.* a valve which stops or closes

up) is formed by a cylinder placed at right angles to the steam pipe, and containing a double piston which can be made automatically to close the steam pipe at any point desired. This is done by connection between the exhaust and one of the piston faces, the difference in pressure causing the displacement of the valve and so closing the steam pipe. To replace the valve, the exhaust is connected with the opposite face of

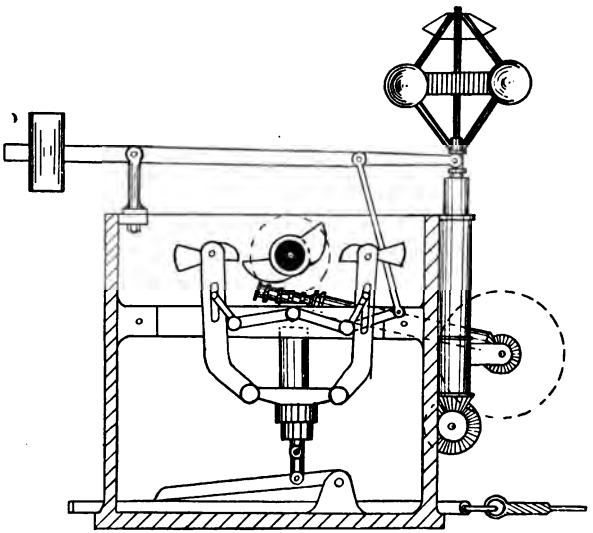


FIG. 148.

the piston. The connection which determines the closing is obtained by means of a finger on the disc of the signal bell, arranged to act at the precise moment when the engineer should reduce the speed of the engine. If the engineer neglects to do this, the obturating valve which acts at each lift will do the work for him automatically. As before stated, the valve will be put in position again by the connection between the exhaust and the opposite face of the piston when the engineer again opens his stop-valve. A second finger is provided on the disc which comes into action in case the engine is started the wrong way, and this prevents overwinding.

Bertram's "Visor."—In addition to the safety hooks, automatic contrivances are in some places in use to cut off steam in case of rapid overwinding or the starting of the cages in the wrong direction. Bertram's "Visor" is designed for this purpose. If the engine is travelling at a high speed, causing the governor to rise, the latter raises a lever (Fig. 148), and causes the tappets to approach the projections on the revolving shaft shown between them. If the engine continues to travel rapidly, the projections will at length come in contact with the tappets, and raise it along with the arms, thus releasing the catch-bar,

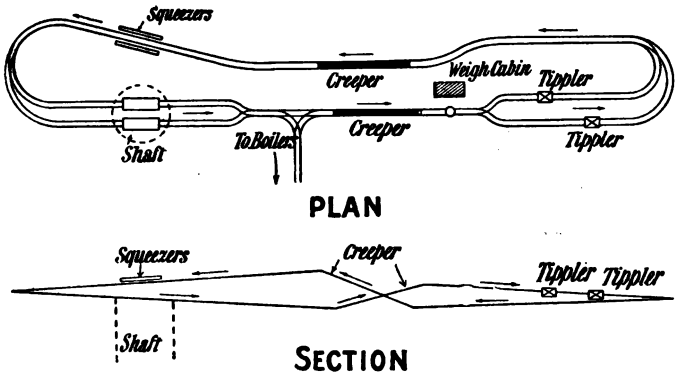


FIG. 149.—Plan and Section of Tramways at Pit Bank.

upon which the brake comes into action, and the steam is shut off.

Banking Arrangements.—For landing or banking the tubs, it is now customary to arrange the gradients of the rails so that the tubs of themselves will run from the cages to the tipplers and back again to the shaft. To do this it will be necessary to have **creepers** (Fig. 149), by means of which tubs may be elevated before or after entering the tippler to a height sufficient to allow of their returning to the cage. Generally the arrangement is as follows: The tubs run out of the cage from one side, pass over the weighing machine, then go slowly down a short distance until they are caught by the carriages of a moving chain and taken up a short incline. This chain moves in the middle of a line of rails over pulleys, a buffer

on the carriage coming in contact with the axle of the tub wheels, thus carrying them along. Arrived at a sufficient height, the tubs pass through the tippler and then run slowly down a short incline until they are again caught by another creeper and elevated to sufficient height to carry them to the cage. From this position the gradient changes and the tubs run slowly round a curve to enter the cage on the opposite side from that on which they came out. If desired, the empty tubs may pass into a pair of **squeezers** (p. 171), from which they may be released one or more at a time as is necessary to fill each deck of the cage, or they may be passed over a **tub controller** of the kind shown in Fig. 150, which holds back the tubs until the lever withdraws the star point *a* from the axle of the tub.

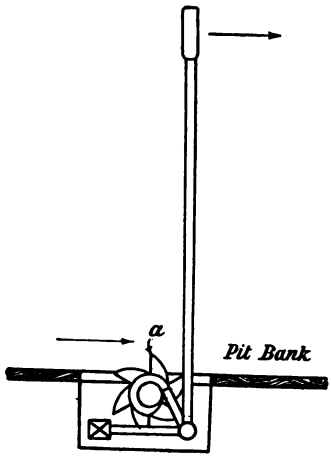


FIG. 150.—Tub Controller used at Pit Bank.

Creepers.—In Fig. 151, *a* is the creeper chain, made of mild steel and jointed together by steel pins, on which are also provided cast-iron rollers (*c*), which serve to minimise friction in pulling the load up the incline. Driving horns (*b*) made of steel plates grip the tub axle in ascending the incline, and are fixed on the chain at suitable distances. Guides (*d*) for the chain and rollers to travel on, consist of steel angles, secured to the framework on which the creeper is fitted. Hexagon tumblers fitted on shafts turn the chain round the end of framework, and a sliding carriage is used to tighten or adjust this as required.

Headgears.—The headgear is the support provided at the top of the shaft for the ropes carrying the cages. It is a frame of wood or iron in which are fixed two large pulleys immediately above the centre of the shaft, over which the ropes pass from the cages to the drum of the engine. The frame consists

generally of six legs: two upright legs placed with their feet near the shaft and on the side nearest the engine house, these legs sustain the greatest portion of the weight; two upright legs on the opposite side of the shaft supporting beams stretched from the two last named for the purpose of carrying the guide rods; two back legs inclined at the most suitable angle for giving greatest support, and so as to prevent the structure being pulled over by the pull of the winding ropes. In addition to these there are other connecting timbers placed so as to form as stable a structure as possible. The *height* of the headgear is fixed so as to allow of a sufficient distance between the pit top and the pulleys. It is clear that if this distance is small, there will be but little margin within which the engineer may move the cages above the pit top without danger of drawing the cage into the pulleys; while on the other hand it is unwise to have an unnecessarily high headgear, as its stability will be reduced. The *width* of the headgear will be determined by the diameter of the shaft. The *inclination* of the back legs is an important matter, as their bottom ends must be placed at such a distance from the front legs as will effectually prevent the latter being pulled over; this inclination is determined upon after a

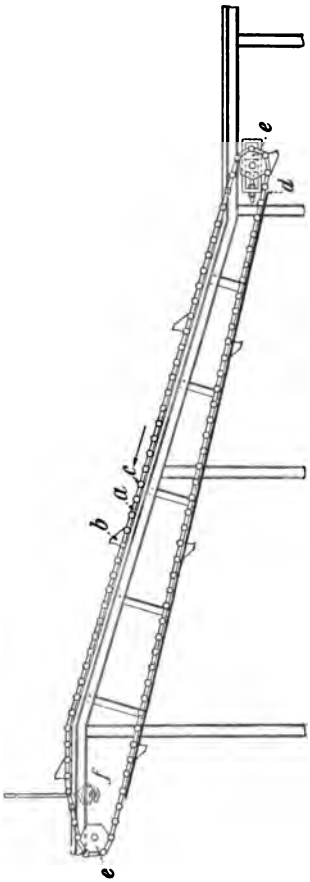


FIG. 151.—Creeper for Elevating Full or Empty Tubs.

careful consideration of the weight of the cages, tubs, coal and rope hanging down the shaft; the power exerted by the engine; the direction of the pull of both ropes; the height of the headgear, and its distance from the centre of the shaft and from the engine.

Winding Calculations.—The Horse Power of an engine may be estimated in two ways:

1. **Nominal.**—This is really the work done by the steam, and is estimated by the quantity of steam in cubic feet passing through the cylinder per minute, and the pressure of the steam in lbs. per square inch upon the piston, as shown by the indicator. This divided by 33,000 gives the nominal Horse Power.

2. **Effective or Useful.**—The nominal work of an engine, which, as has been seen, is the total work of the steam, is divided into two parts, namely, that spent in moving the various working parts of the engine itself—piston and piston rod, crank, crank-shaft and drum. This is generally assumed to take up about one-third of the whole work of the steam; the other two-thirds is the useful or effective work, commonly called the effective H.P. In this connection it is said that the modulus of the engine is 0·66 or two-thirds. Of course the effective H.P. will be sometimes over and sometimes under two-thirds, but this is a fair average. The same distinction holds good for other machinery, pumps, fans, hauling engines, etc.

EXAMPLES. 1. What is the nominal Horse Power (H.P.) of a winding engine with a 28 in. diameter cylinder, piston speed 300 feet per minute and indicated steam pressure 40 lbs. per square inch? *

$$Answer: \frac{28 \times 0{\cdot}7854 \times 300 \times 40}{33{,}000} = \underline{223{\cdot}9 \text{ nominal H.P.}}$$

2. What is the effective H.P. in the last case, the modulus of the engine being 0·66?

$$Answer: 223{\cdot}9 \times 0{\cdot}66 = \underline{149{\cdot}2 \text{ effective H.P.}}$$

---

* Area of any circle $= 3{\cdot}1416 \times (\text{radius of circle})^2$,

$$\text{or} = \frac{3{\cdot}1416}{4} = 0{\cdot}7854.$$

3. The modulus of winding engine is 0·7, its effective H.P. is 500, its cylinder is 40 in. diameter and its piston speed 400 ft. per minute. What is the indicated steam pressure?

$$\text{Here nominal H.P.} = \frac{500}{0{\cdot}7} = 714{\cdot}3.$$

Units of work per minute of

$$714{\cdot}3 \text{ nominal H.P.} = 714{\cdot}3 \times 33{,}000,$$

and units of work per minute

$$\text{for each pound of steam} = 40 \times 0{\cdot}7854 \times 400;$$

$$\therefore \frac{714{\cdot}3 \times 33{,}000}{40^2 \times 0{\cdot}7854 \times 400} = \text{lbs. pressure} = 46{\cdot}9 \textit{ Answer.}$$

Questions on Chapter XI.

1. Tabulate carefully the whole of the arrangements which are necessary for the complete equipment of a modern colliery shaft, and describe the purpose for which each is required.

2. Give a complete description of a cage with two decks suitable for a load of four mine waggons, two in each deck, standing end to end. Show by sketches the construction of the cage, and how it is attached to the winding rope. Show by sketch how such a cage may be attached to rope guides, and describe the best means known to you for keeping the waggons in position while the cage is passing up and down the shaft.

3. Describe some method of mechanically changing the waggons on a cage, that is to say, removing the full waggons from the cage and replacing them by empties. (1902.)

4. Describe and sketch a good form of keps for use under the cages.

5. Describe the various kinds of wire rope employed in winding and hauling. State in particular the advantages and disadvantages of employing "shaped" wires in the manufacture of wire ropes. (1901.)

6. Give the weight per fathom, ultimate strength and safe working load of a crucible steel wire rope 4 inches in circumference. (1895.)

7. What are the causes of the deterioration of wire ropes used for winding? (1902.)

8. Describe an appliance in use (*a*) for preventing overwinding, (*b*) and another for remedying the effects of the overwind. (1901.)

9. Describe the arrangements necessary at the pit top for landing or banking a large number of tubs daily.

10. What points have to be taken into consideration in deciding upon the size and construction of the headgear?

CHAPTER XII.

MINE DRAINAGE.

DIRECTLY the colliery engineer gets below the surface of the ground he is liable to be impeded by water, which may constantly increase in quantity during the process of sinking, and, indeed, during the whole time of working. The question of how to deal with the water at the lowest cost, and with the smallest injury to men and workings requires the most careful consideration. In some districts, owing to the conformation of the adjacent lands, it has been found practicable to collect considerable bodies of water and to divert them, so as to prevent their getting into the shafts and workings. When this is possible it should be done; but, as a rule, it will be impossible to avoid the more expensive and troublesome methods of drainage.

Sources of Water.—Water is met with

(1) in the shafts,

(2) in the "Higher Side" workings,

(3) in the "Lower Side" workings,

and each of these sources and conditions will be referred to in order.

1. **Water in the Shaft.**—There are many sources from which water finds its way into the shaft. It may come from adjoining land, which may be slightly higher than the shaft; or, from the mossy ground, occurring on the surface above the seams of coal, which frequently holds large quantities of water. The quicksands, sandstones, and other porous rocks which have to be sunk through, often act as great reservoirs for water. Water also comes to the shaft from adjoining collieries, from old workings, or from the mine itself. From any, or several,

of these sources which may be tapped during the sinking of a shaft, quantities varying from a few hundreds to many thousands of gallons of water per hour may have to be dealt with.

2. **Water above the Pit Level, or "Higher Side" Water.**—Except where all the coal to be worked at a colliery lies on the "higher" or the "lower side," *i.e.* except in cases where the shaft is at the highest or the lowest point of the estate, a road is generally driven from the shaft towards the boundary on each side, in what is called a **level** direction. As a matter of fact, it is not strictly a level road, but is driven in such a direction as to give it a rise of from 1 in 100 to 1 in 300, so as to allow water that may come into it at any point to flow towards the shaft freely. Of course, the greater the inclination, the better the water course, but the smaller is the quantity of coal left above the road. All coal above these two roads is called "higher side" coal and the whole length of road from boundary to boundary is spoken of as the **pit level**. It is in this "higher side" coal that the water from other mines is most frequently met with; sometimes, indeed, unexpectedly, and with disastrous results. But in ordinary circumstances, water is frequently encountered by the miner at the "higher side" working face, or in the roof; and it requires careful and constant attention so to collect and conduct it down to the level that it will cause the least trouble, delay, and loss in the working, and the least injury and inconvenience to the men. Of course, no power but that of gravity is required to conduct this water to the shaft.

3. **Water below the Pit Level, or "Lower Side" Water.**—In this case as in the last, careful attention is needed to keep the water away from the men and from the places where men are working, and to conduct it to some given point at the lower side of the workings. Here, however, it has to be dealt with again and to be raised by some means to the pit shaft.

We have already considered various methods of dealing with the water met with during the sinking operations, and it now remains to refer to the methods adopted for getting the water from the mine to the top of the shaft, or of holding it back entirely during the progress of the working.

Dams.—Underground dams, like the tubbing in shafts, are for the purpose of holding water back. Wood, bricks, stone,

concrete, and clay are used in their construction, according to whether the dam is intended to be of a temporary or a permanent character, or meant to resist a low, a high, or a medium pressure of water.[1] The brick and stone dams, if disturbed or broken by subsidence from other workings, are afterwards less perfect than the wood, or concrete, or clay dams. Concrete and clay in alternate bands form a good barrier, but balks of timber placed longitudinally—that is in the direction of the road—form, perhaps, the most trustworthy dam where great pressure is expected. Of course, the first step in preparing to put in a dam is to ascertain the probable head of water; the next to fix upon a place where the roof, the floor, and the sides can be made perfectly water-tight; and the third to select a position where the exact height and width of the dam can be determined.

Strength of Dam.—When the head of water and the sectional area of the dam are known, the required strength of the dam can be estimated. As **the strength required is directly proportional to the head of water and the sectional area of the road,** the necessary strength is easily ascertained. As in the case of tubbing, a very good margin of strength should always be allowed.

EXAMPLE.—Assuming the road to be 6 feet square and the head of water 300 feet, there will be a total pressure upon the dam as follows:

The pressure of water in pipes is equal to 0·434 lbs. per sq. inch per foot in depth.

$\therefore$ 300 ft. $\times$ 0·434 lbs. pressure per sq. inch = 130·2 lbs. per sq. inch.

Area of roadway $6 \times 6 = 36$ sq. ft.

$= 36 \times 144 = 5184$ sq. inches;

130·2 lbs. $\times$ 5184 sq. ins. = 674956·8 lbs. total pressure;

$$\frac{674956 \cdot 8}{2240} = 301 \cdot 3 \text{ tons.}$$

In this case a dam consisting of oak logs laid side by side, and one row above another, tapered so that the whole forms a pyramidal wedge, the thick end being placed next to the water, would be suitable. The dam in this case should be about 5 feet

[1] Clay dams are, however, not put in without a protecting wall of brick, stone, or wood on each side.

thick. The roadway in which the dam is to be constructed must be cut at the sides (Fig. 152) so that the latter are exactly the same size and shape as the wedge, in order that the logs may fit exactly. The roof, floor, and sides must either be cut very evenly so as to form a tight joint, or the spaces must be caulked with moss or oakum. When all the pieces have been laid in position, the whole must be wedged as carefully and completely as in the case of tubbing, and in precisely the same way (p. 77).

In constructing dams of brick or stone, the sides of the road must be cut out so that they will form an abutment for the dam, which must be semi-circular, to rest upon; in other words, to receive the thrust.

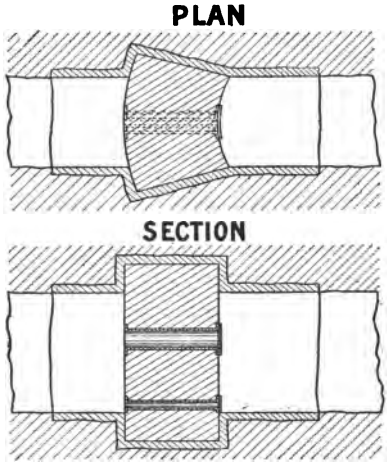


FIG. 152.—Underground Dam.

A good form of dam consists of alternate rings, 18 inches thick, of good, strong, well-burnt bricks and of concrete, the joints between the brick or stone and the roof, floor, and sides being filled with concrete made of sharp sand, rough cinders, and good cement or hydraulic lime. The bricks or stone should be set in cement. Four arches of bricks or stones and concrete, each 18 inches thick, are required for a heading of 300 feet, and a sectional area of 36 square feet. During the process of constructing the dam, pipes must be inserted to convey the water through, and an additional pipe should be inserted near the roof to allow all the air behind the dam to escape. Taps may be placed in the lower pipes to draw water off if desired at any future time. In the case of dams constructed of wood, which have to be wedged from the water side of the dam, it is necessary to insert a pipe through which a man may come when he has finished wedging up. This pipe is afterwards

plugged on the water side, the plug being drawn in by a chain and tightened by a screw or lever.

Drainage Tunnels.—These tunnels, for draining mines of water, are very useful in hilly districts where there is much coal lying above the general level of the country.

Take a case where a tunnel is driven into the side of a hill and rising at the rate of 1 in 130 and draining all the mines through which it may pass. In this and in similar cases a pair of levels are driven and serve for air, water, hauling, and travelling. In this way many of the mines in the North and North East of Lancashire are at present drained.

Another case with which the author has had to do is one where a tunnel has been driven 1½ miles in length to a pumping shaft, taking away 30 yards in vertical height from the lift of the pumps; the water runs along the tunnel to a point on the surface, where it joins a stream, carrying it eventually to the sea. This is a tunnel driven expressly for the purpose of taking all surface water above that level.

Perhaps the most remarkable and most useful colliery tunnel ever driven in England is the one constructed by the great Duke of Bridgewater, under the supervision of his equally great engineer, Brindley. This tunnel, entering the hill-side near what is known as the Bridgewater Canal, at Worsley, a few miles from Manchester, is driven in a direction following the rise of the mines. It is locally known as the Duke's boat level. Being driven in the direction of the rise of the mines and perfectly level, it comes in turn to every mine of the Middle Series of Coal which is under it at Worsley. In this way it crosses in succession the Trencherbone, Cannel, Plodder, Yard, Half-yard, and Three-quarter Mines; and where it reaches each mine a level has been driven each way in that mine from the main level. Thus, a district of many square miles, probably five miles square, has been completely intersected under the surface by boat levels, where the coal is loaded in the boats and brought along the canals, for such the levels were, by men who lay upon their backs on the coal in the boats and propelled the latter along by pushing against the roof with their feet.

The Syphon.—This is an arrangement of pipes by which water may be forced by the simple pressure of the atmosphere

from a given level to some other level a little lower. The apparatus (Fig. 153) is arranged simply for the creation of a vacuum by filling one leg of a bent pipe with water, the other leg being at the same time full, and then releasing the water in the first one. As it runs down it leaves, or would leave, a space behind it; but this is instantly filled by water from the first, which is forced up by the atmosphere.

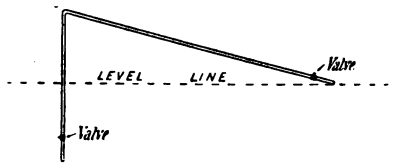


FIG. 153.—Syphon.

Pumping Machinery.—Undoubtedly the best means of raising large quantities of water is by pumps. These are placed near the accumulation and are worked by power transmitted from the surface either in the form of steam, compressed air, electricity, water, or rods. By means of pipes of sufficient capacity the water is conveyed to the pit bottom and up the shaft to the colliery reservoirs or streams.

By Rods.—The best illustration of this method as applied to mine drainage is where the pumping engine is placed on the surface and connected to the bucket or plunger by rods. The most common form is a square pitch-pine rod. These rods vary in size from 5 or 6 inches to 12 or 14 inches square, and are attached to each other by iron straps and bolts, which also add considerably to their strength. At distances of 25 or 30 feet apart, beams are fixed in the shaft, and short pieces are bolted to them to steady the rods and keep them as nearly in a vertical line as possible in the down stroke. Where these **stays** are put in, the rods are protected from wear by boards nailed to them, which when worn down to a certain thickness can be renewed by others. These are called **rubbing boards**. One advantage of wooden rods is that they are buoyed up somewhat by the water in the pipes in which they work, but against this is to be set the disadvantage of taking up much room in the pipes, and so causing the water to have a greater velocity. Wooden rods are also used frequently down inclines, where they give motion to a pump at the bottom, which may be either of the **lift** or **force** type. If the former, a waggon running on rails and weighted with iron is used to pull down the rods and

bucket after the water has been lifted. If of the force type it is used to assist in forcing up the water. Where an endless rope is used in the incline, the better plan is to attach the waggon by means of a short rope to the wheel of the hauling rope. Where a mine is not very steep, a considerable distance may be drained by the syphon (p. 233).

By Water.—In mines, power is generally transmitted by water in the following way: the water is taken from the pipes in the shaft at the highest point so that the smallest quantity possible may be used, and this, as it falls a considerable distance, is enabled to force a greater quantity from the workings on the deep to the foot of the pumps in the shaft. The weight in pounds of the water lifted from the down-brow, multiplied by the height lifted in feet, plus work due to friction, must be less than the weight of water falling multiplied by the height from which it falls.

By Steam, Compressed Air and Electricity.—We have already made comparisons in the use of these powers for various other purposes underground, and the same advantages or disadvantages then noted will, in most respects, apply here; but one or two further considerations in regard to steam, compressed air and electricity ought to be mentioned.

We have shown that it is unwise to carry steam into the workings because of its bad effect upon the strata, which it causes to **disintegrate** or break up, but as pumps are often required near the pit bottom, a steam driven pump could be used near the bottom of the upcast shaft without any bad effect.

On the other hand, electrically-driven pumps, which would be considered dangerous by some engineers, could be safely used near the bottom of the downcast shaft without the danger of igniting gas.

Again, compressed air, the chief drawback of which is loss of efficiency in transmission, would if applied near the bottom, either of the downcast or upcast, lose little power in so short a distance.

Advantages of Electric Power for Pumps.—Electricity as a motive power for pumps has advantages which cannot be overlooked, especially when we remember that its only drawback, viz. a certain degree of danger when used in a gassy mine, is being gradually eliminated by the use of Alternating

Current motors, carefully enclosed. Its advantages for pumping are:

1st. That it can be installed quickly in case of emergency; this can be done with a minimum amount of apparatus and of labour and with a maximum efficiency. It invariably happens that a sudden inrush of water could be prevented from doing serious harm if suitable pumps could be easily and quickly set up to dislodge it. It generally happens also that accumulations of water occur at long distances from the shaft and, if any other power is used, great loss of efficiency cannot be avoided.

2nd. With many recently devised pumps it has been found possible to lift the water much greater heights than formerly. Most of these pumps are electrically-driven, and, in fact, there can be no question that it is the only suitable power that can be used at mines for driving the high-speed pumps mentioned.

3rd. We have previously said that electricity is a power the strength of which can be easily varied, and this is a great advantage in pumping installations. It is usual in extensive collieries to have to deal with large volumes of water, and it is necessary to have a series of pumps placed at different points in the shaft or about the workings, of varied capacities and consequently varied speeds, each requiring a different amount of power for driving. It would be very difficult to drive these from a central station by any other power than electricity.

Pumps.—Pumps for colliery purposes are chiefly of the **Lift or Bucket Pump** type or **Force or Plunger** type, but there are some others which will also be described.

The Lift Pump (Fig. 154) consists of a working barrel (*a*), so called because in it the bucket travels up and down; a suction pipe (*b*) with holes (*c*) for the admission of water and provided with a clack piece (*d*) at the top, holding the water through which the bucket (*e*) passes in its descent, this piece having a door (*f*) for access to this clack or the bucket clack; the rising main (*g*), up which the water travels to its point of delivery; and the rods (*h*).

Its action is as follows: When the rods carrying the bucket (*e*) are raised, the clack (*d*) opens, admitting the water from the suction pipe (*b*) forced up by atmospheric pressure, the

clacks in the bucket being held down by the weight of the water above them. In this way the water is lifted into the rising main (*g*). When the bucket reaches the top, the rods

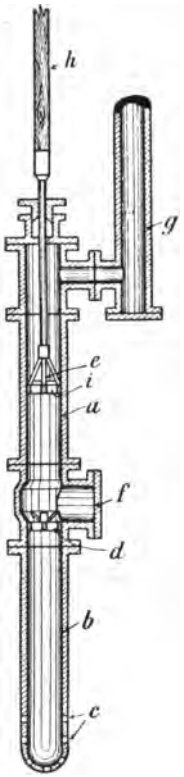


FIG. 154.—Lift or Bucket Pump.

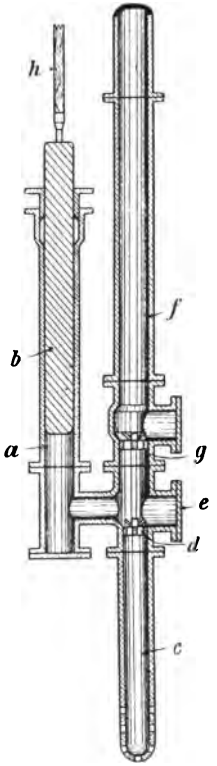


FIG. 155.—Force or Plunger Pump.

begin to travel in the opposite direction, and the valves in the bucket open as the latter travels downwards. The valves at *d* are meanwhile closed.

From its construction it follows that the lift or bucket pump can only be used when the engine is above the point to which the water has to be lifted. The bucket gets under the water

because the clacks or valves open upwards to allow it to pass freely down the working barrel; but directly the pump bucket stops, the valve begins to fall down and close, the water above holding them tight down whilst the upward stroke is made and the water is lifted. It is easy to see that in this case the bucket must be lifted by something which is above it even at its highest point.

The Force or Plunger Pump (Fig. 155) consists of: A ram chamber (*a*), in which a ram (sometimes called a piston) works, and a ram or plunger (*b*); in addition there are a suction pipe (*c*) with clack piece (*d*) at the top, together with clack door (*e*), the rising main (*f*) with the necessary valves or clacks (*g*) for admitting and holding the water, and the rods (*h*).

Its action is as follows: When the rods (*h*) carrying the plunger or ram (*b*) are moving downwards, the valve (*d*) is closed, and the water in the pump barrel is forced past valves (*g*) into the rising main. On moving upwards, the valve (*d*) opens, water is forced into the chamber (*a*) by atmospheric pressure, filling the chamber again. It is evident that as there is no clack in the ram necessitating its vertical position, as there is in the bucket, it can move in any required direction. We thus find it placed on the surface, or rather above the water, which it forces down the ram chamber and up the ascension pipes; or again, we find it in the mine itself working horizontally, but forcing the water up the rising main.

Cornish Pumps.—Pumps operated by rods are commonly called Cornish pumps. They are generally single acting, the motion being transmitted through a moving beam placed directly over the shaft. In modern plants it is usual to employ a type of engine such as the **Corliss,** which can be provided with a governor to guard against the possibility of the engine running away in case an accident should happen to the rods.

Simple and Duplex Pumps.—A *Simple Pump* is one in which a steam cylinder is connected directly to the water cylinder, the steam valves being operated by tappets. A pump of this kind is to a certain extent dependent on its inertia, or tendency to remain at rest, at certain points of the stroke, so as to ensure the movement of the valves, and thus it will not start from any position in the cylinder, but is liable to stop at times.

In the case of a *Duplex Pump* two steam cylinders and two water cylinders are arranged side by side, the valves being so placed that when one piston is at mid-stroke it throws open the steam valve for the other cylinder. Thus the pump is enabled to start from any point, and it is not stalled or stopped for lack of steam, due to the position of the valves.

The Pulsometer.—One of the first things resorted to when winding-in barrels have been found inadequate, is a peculiar form of pump called the Pulsometer. It consists of practically one piece of mechanism divided into different chambers. The two principal ones *AA* (Fig. 156) may be termed water chambers, into which water is forced by atmospheric pressure. The action of the pump as well as its construction is very simple. The two chambers are separated by an air chamber *B*, except at the top, where they come together like two bottle necks, and at this point, and resting upon the air chamber, is a ball, *I*, acting as a valve which moves alternately from side to side, first covering the top of one water chamber and then the other. When the pump is started, the ball is of course covering one of the necks. Steam is turned on and rushes down the open neck, meeting the water in that chamber with a considerable rush, and forcing it down the chamber and through the delivery passage *F*, to the ascension pipe *D*. When the surface of the descending water gets down to a certain point, the steam which has been forcing it down suddenly condenses, creating a vacuum in that chamber. At this instant, three movements take place: water rushes up the suction pipe *C* to re-fill the chamber; the ball at the top of the chamber is pushed over; and the other chamber-neck, being now open, steam rushes down into it and the process is repeated.

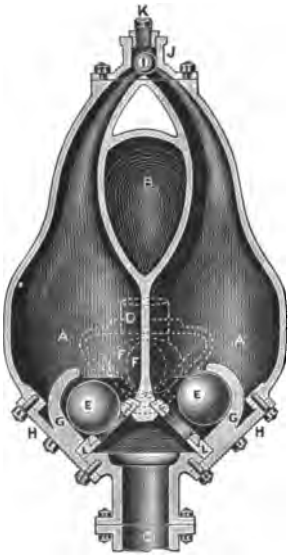


FIG. 156.—The Pulsometer.

The pump, especially for sinking purposes, possesses several advantages. It saves time in being brought into use, as there is no engine room to be cut into the pit side. The pump, steam and exhaust pipes and delivery pipes can all be slung in ropes or chains, and lowered as required to keep near the sinkers. Unlike most other pumps, it is not stopped by mud or small stones, but will take anything that will pass through the clacks. One other great advantage it has, namely, that it can lift a very large volume of water.

It has two defects : it is somewhat wasteful of steam, and it is limited to a comparatively short-distance vertical throw, namely, something like 100 feet. Still, with these drawbacks, it is one of the most useful means of dealing with water temporarily, *e.g.* during sinking ; and when considerable depths have to be provided for, pulsometers are suspended at different heights, and the water lifted from one to another. As much as 150,000 gallons an hour have been dealt with by pulsometers in one shaft.

Safety Catches for Pumps.—These are very simple arrangements. Suitable places are selected at given distances down the shaft, where two strong beams (generally termed bearers) can be built into the sides, one behind and the other in front of the main pump or spear rod. Upon these are placed two blocks of wood of considerable thickness ; these are bolted to the beams. Side pieces are bolted to the pump rod in such a position that when the rod is at its lowest point, they may rest upon the blocks. The number of these catches is regulated by the weight of the rods, buckets, etc., descending at one time, and they must be so finely fixed in respect to height that no catch falls with force upon the bearer, but each one just rests upon it before the upward stroke begins.

Columns.—This is the term applied to the ascension pipes up which the water rises to the point of delivery. They are generally of cast iron in 9-ft. lengths and flanged ; the pressure upon the pipes at any point is found by multiplying the height in feet by 0·434, the result being lbs. per sq. inch.

Thus : A cubic foot of water weighs 62·5 lbs.

This divided by 144 will give the weight in lbs. of a column of water 1 square inch in area and 1 foot high.

$$\frac{62{\cdot}5}{144} = 0{\cdot}434 \text{ lbs.}$$

The pipes must be carefully supported in the shaft. One method of doing this is shown in Fig. 157. A bearer fixed in the shaft side has a metal strap (*a*) attached to it by means of bolt (*c*). The strap passes round the pipe and holds it in position, while the weight is taken by arranging for the flange (*d*) of the pipe to rest upon the bearer.

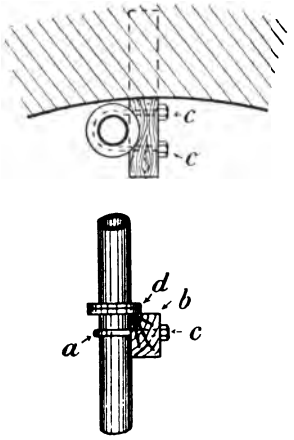


Fig. 157.—Method of Supporting Columns in Shaft by means of Straps.

Another method is shown in Fig. 158. Here three beams *a*, *b*, *c* are used, secured together firmly, the flange (*d*) resting upon the timbers as shown.

Clacks and Valves for Buckets and Rams.—These are of two types: those having fixed hinges and acting like **trap doors**, opening at one side only, and those having spindles around which a **disc** rises and falls. The former are generally used in the bucket or lift pump; the latter, where the valve seating is stationary either for lift or force pumps. The clacks of a bucket are double, the hinge of each being in the centre. Where the water is good and not corrosive, the valve is of leather, with an iron plate over it to make it stronger and heavier, and cause it to drop down more quickly.

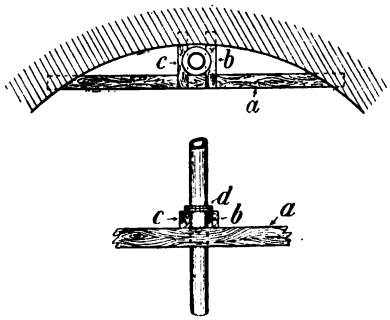


Fig. 158.—Method of Supporting Columns in Shaft by means of Beams.

Where the water is corrosive, wood or brass is used for the seatings as well as for the valves. Great care is required in

order to have the valve openings exactly of the right size both in width and in height of lift, so that whilst the water is freely admitted at the proper time, the valve closes, so that there is the least possible loss of water, or **slip** as it is termed.

Corrosive Water.—The water in mines is rendered corrosive by passing through various substances in and about the mine. In passing over the surface it may come in contact with cinder heaps, and sulphurous or sulphuric acid may be formed with the water. It may pass over iron and cause the iron to rob the air of oxygen, thus producing oxide of iron. The fumes from the furnace or underground boilers may come in contact with water in the shaft, and this produces various acids, the effects of which are seen on iron curbs and iron tubbing if there be any. Various minerals in the mine containing sulphur, iron and copper pyrites, and other substances containing sulphides, render water injurious to pumps. For these reasons tubbing in shafts has to be painted, bricked in, or otherwise protected; whilst the working barrels of pumps are sometimes lined with brass; and buckets and other parts have to be frequently renewed.

Power of Pumping Engines.—The **power** or **duty** of an engine is the amount of work it does per unit of coal consumed.

In pumping engines this is estimated by the water in lbs. weight, lifted one foot high, the unit being one lb. lifted one foot per lb. of coal burnt.

Let a = area in sq. inches of plunger.
p = pressure upon each sq. inch of plunger.
s = distance travelled by plunger per hour.
c = weight of coals consumed in lbs. per hour.
d = duty.

Then $$\frac{a \times p \times s}{c} = d.$$

EXAMPLE. A pumping engine has a 21-in. diameter plunger; the head of water is 300 feet; the plunger travels 5,000 feet per hour; and the coal burnt per hour is 1,000 lbs. What is the duty of the engine?

EXAMPLE. What is the weight of 1 lineal foot of pipe, 12-in. internal diameter and 14-in. external diameter?

$\frac{12+14}{2} \times 3{\cdot}1416 \times 12 = 490$ sq. in. per ft. in length, and as the thickness is 1 inch the cubical contents are 490 cubic inches.

$$\therefore \text{ weight} = \frac{490 \times 453{\cdot}125}{1728} = 128{\cdot}5 \text{ lbs. per lineal foot of pipe.}$$

Note.—The two flanges of a pipe are generally computed to be equal to one foot of the pipe. Hence, in estimating the weights of a column of pipes of a given height, it is necessary to add $\frac{1}{7}$ of the weight of the straight pipes.

Questions on Chapter XII.

1. What are the main sources of water met with underground or in the shaft?
2. With what object are dams put in underground roadways? How would you erect a dam underground?
3. How may tunnels be used for drainage purposes?
4. How can a syphon be used in lifting water underground? (1894.)
5. Compare the various forms of power as applied to pumping machinery.
6. Explain the action of the common lifting pump as used in mine shafts. (1903.)
7. What is the Pulsometer, and how is it used as a mining pump? (1898.)
8. It is required to raise 300 gallons of water a minute from a mine 400 yards deep. Give a general sketch, with leading dimensions, of the plant you would prefer for the work. (1897.)
9. A large sinking shaft 200 yards deep is troubled with an inflow of 20,000 gallons of water an hour. How would you raise this water? Explain fully with sketches. (1902.)
10. How is the power of a pumping engine obtained? What must be the power of a pumping engine with a head of water of 500 ft., the diameter of plunger being 24 in., the plunger travelling at the rate of 5,000 ft. per minute, coal burnt per hour being 1,500 lbs.?

CHAPTER XIII.

PRINCIPLES OF VENTILATION.

Need for Ventilation.—Perhaps the most important of all the rules of the Coal Mines Regulation Act is the first one, which reads as follows:

"An adequate amount of ventilation shall be constantly produced in every mine to dilute and render harmless noxious gases to such an extent that the working places of the shafts, levels, stables and workings of the mine, and the travelling roads to and from those working places, shall be in a fit state for working and passing therein."

"In the case of mines required by this Act to be under the control of a certified manager, the quantity of air in the respective splits or currents shall at least once in every month be measured and entered in a book to be kept for the purpose at the mine."

We thus see that in this rule some reference is made to all the important branches of the subject of ventilation into which the latter may be divided. These are as follows:

1. The Causes of the Pollution of the Air of the Mine.
2. Quantity of Air Required.
3. The Production of an Air Current.
4. The Distribution of the Current through the Roadways and Workings of the Mine.
5. Measuring and Recording the Ventilation.

Causes of the Pollution of the Air in Mines.—All the gases found in mines are to a certain extent dangerous, either because of their inflammable properties or their depressing or suffocating effect upon the workmen. The **natural** gases which find

their way into mines, which it is so necessary to dilute and render harmless by an adequate supply of fresh air, are produced in different ways: some are formed owing to the slow combustion taking place in the goaves and abandoned portions of the workings; others are given off by the coal or the strata immediately above or beneath the seam. These gases will be referred to separately.

The artificial causes of the pollution of the air may be given as follows: (*a*) breathing of men and animals, (*b*) burning of lamps, (*c*) firing of shots, (*d*) creation of dust in the boring of holes in rock or coal, and the breaking of coal, (*e*) the decay of timber, and (*f*) the escape of steam.

Quantities of Air Required.—If we had only to estimate the amount of air required to purify the atmosphere from the effects of the breathing of men and the burning of lamps, this would be an easy task; thus, say, when a man is at work he breathes 30 times a minute; at each inspiration he takes in 30 cubic inches of air, at each expiration he breathes out 22·5 cubic inches of vitiated air. To keep the air fit for health he wants:

$$\frac{22{\cdot}5 \times 20 \times 30}{1{,}728} = 11{\cdot}7176 \text{ cubic feet of fresh air per minute.}$$

If we allow the same amount for his lamp we have 23·4 for each man and his lamp per minute; but these figures of course are below what is wanted, there are other causes of the pollution of the mine air to be taken into consideration. When we remember that for every cubic foot of fire damp we need 40 cubic feet of fresh air to prevent the former showing a cap on the flame of the safety lamp, and that where carbon dioxide is produced we require 2,000 times its volume of air to keep the mine healthy, it is clear that a large supply of fresh air will be needed. As a basis for calculation, a minimum quantity is generally allowed of 100 cubic feet per man per minute, with large additions where carbon dioxide (CO_2), firedamp (CH_4), and carbon-monoxide (CO) are freely given off, say 400 or 500 cubic feet per man for deep, extensive, thick and fiery mines.

It may be said that a mine is adequately ventilated when the speed of the current is not less at any time in any part of the roadways or workings than that which is necessary to render poisonous gases harmless and to keep the percentage of firedamp below the point at which it may be seen in a good safety lamp.

Production of the Current.—To produce a current in the shafts, roadways and workings of the mine, it is necessary to create a difference in the pressure of the air in the shafts. This may be done in one of three ways :

(1) By warming the air in one shaft by means of a **furnace**, thus reducing the barometric pressure in the shaft.

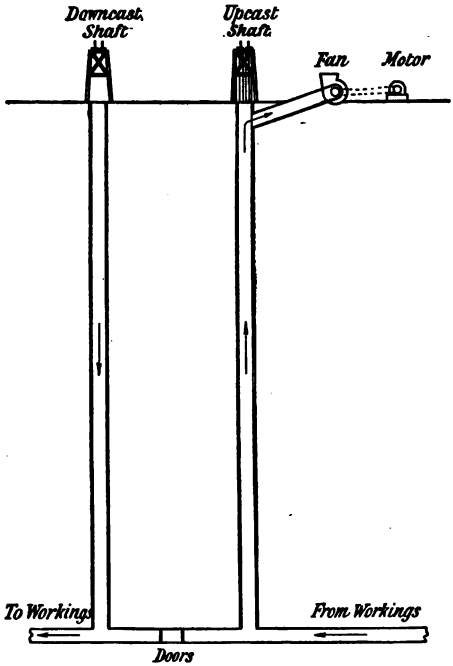


FIG. 159.

(2) By lightening the air of one shaft by means of an **exhaust fan** placed at the top of the shaft (Fig. 159), thus producing the same effect.

(3) By compressing the air in one shaft by means of a **force fan** placed near the shaft, thus increasing barometric pressure.

Ventilating Pressure.—All these methods have the same effect, namely, the creation of a difference in the pressure of the air of the two shafts, and the difference of pressure obtained is termed

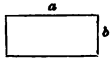
"The Ventilating Pressure." The greater the difference, therefore the stronger will be the current.

It is this pressure which sets and keeps the air in motion. We may perhaps best explain the term Ventilating Pressure by comparing the two shafts of a mine to the two ends of a pair of scales. If a weight of 10 lbs. were placed at each end of the scales, neither end would go up or down—the scales would be balanced. This position would represent the two shafts without artificial ventilation—in other words, without any ventilating pressure. If now the 10-lbs. weight were taken out of one end of the scales and a 9-lbs. weight substituted, the 10-lbs. end would at once go down. This action would represent the lightening of the air in the upcast shaft, and its consequent ascension followed by the descent of the air in the downcast. Assuming that the difference of the weights of the air amounted to 1 lb. per square foot, the term used to express it would be "a Ventilating Pressure of 1 lb. per square foot."

Power.—While the term pressure is used to express the intensity and not the amount of force extended in producing a current underground—in other words, while it expresses the force upon each square foot across the air-way—the term **power** expresses the amount of work done in a certain time in driving any given volume or quantity of air with a given pressure. It is expressed in foot-lbs. per minute, and is found by multiplying the quantity of air in cubic feet per minute by the pressure in lbs. required to remove it. This gives the foot-lbs. per minute, and the value divided by 33,000 gives the air Horse-Power (H.P.). Just as the H.P. of a steam engine is calculated by multiplying the steam pressure by the quantity of steam passing through the cylinders, so the H.P. in the air is ascertained by multiplying the air pressure by quantity of air passing.

Area.—Roadways underground have length, breadth, and width, but in dealing with area and perimeter the length is not considered. The area of a road is the height multiplied by the width.

Taking a road 8 feet high by 8 wide, the area is $8 \times 8 = 64$ square feet. In a circular road 8 feet diameter, the area is $8 \times 8 \times 0{\cdot}7854 = 50{\cdot}2656$.



$a \times b = \text{area}$.

Perimeter.—The perimeter of a road is the distance measured along the roof, sides, and floor in a plane at right angles to the length of the road. Thus in a road 8 feet high by 8 feet wide, the perimeter is $8+8+8+8=32$ feet. In a circular road 8 feet diameter, the perimeter is $8\times3{\cdot}1416=25{\cdot}1328$ feet.

Rubbing Surface.—By rubbing surface is meant the surface of roadway exposed to the current, and its extent is obtained by multiplying the perimeter of a roadway by its length.

Velocity of an air current is the speed at which a current flows along the air-ways, and is measured by means of an anemometer.

The Water-Gauge Equivalent is the pressure in lbs. per square foot required to produce the ventilating current.

Coefficient of Friction.—One other term used constantly in ventilating work has yet to be explained, and that is the **Coefficient of Friction**, by which is meant the ratio of the work to the resistance in overcoming friction. Just as water meets with the resistance of friction and has its coefficient, and as all machinery meets with frictional resistance and different machines have their respective coefficients, so air has a coefficient of friction.

Much labour has been spent in experiments upon this subject, especially upon the Continent, with the view of getting trustworthy results. The late Mr. Atkinson, H.M. Inspector of Mines for Durham, published, forty years ago, a work on "Ventilation," which has ever since been considered a standard work. But whereas he puts the coefficient of friction at "0·26881 of a foot in height of an air column, one foot in area for each square foot of rubbing surface for every 1,000 feet of air passing per minute," weighing 0·0092 lb., later experiments have led to the adoption of a column of air 0·114 in height instead of 0·26881. It will be easily understood that the difference is due to the irregularities in the sides; and possibly greater attention has been paid during the intervening forty years to the advantages of having even surfaces, since friction is of much more importance now, with workings so extensive and quantities of air so large. Probably 0·26881 was right forty-nine years ago, as 0·114 may be correct now. However, opinion is still divided upon the subject, some examiners for manager's certificates still taking Atkinson's as the standard work, and others J. Stanley James's, who adopts the latter results, 0·114.

Laws relating to the Passage of the Air through the Mine.—It is necessary to understand what are known as the **three laws of friction**, as upon these depend the successful or unsuccessful ventilation of the mines, and these laws must not be lost sight of when arrangements are being made for the carrying of the current to the remote parts of the mine. They are as follows:

1. *Frictional Resistance varies directly as the Extent of Rubbing Surface.*—If two roads of equal area have equal perimeters, the shortest will have the least friction, or, in roads of equal length and area, the one with the least perimeter will offer the least frictional resistance.

2. *Frictional Resistance varies directly as the Square of the Velocity.*—If the velocity be doubled, the resistance will be fourfold, as double the quantity of air passes, each particle meeting with double resistance.

3. *The Pressure required to overcome Friction varies inversely as the Area.*—If two air-ways have equal velocities of air and equal rubbing surfaces, then if the area of one be double that of the other, only half the pressure per square foot will be required for the large one that will be needed for the small one.

When a change in velocity of a current takes place in the same airway, a change also takes place in the pressure applied and the resistance offered, amounting, in proportion, to the square of the velocity; *i.e.* if the velocity is doubled the pressure and resistance are increased four times their former amount, and if the velocity is trebled the pressure and resistance are increased nine times their original amount. Again, it follows that if the velocity has been doubled and the pressure has been increased four times, then the power—the amount of work done—has been increased eight times as it is now, forcing twice the amount of air through at four times the pressure, and similarly if the air is trebled the power amounts to twenty-seven times its former amount, being three times the quantity at nine times the pressure. The power thus varies according to the cube of the velocity.

Consequent upon these principles the following points require attention in setting out roads underground:

(*a*) *The larger the Air-ways the better:* first, because for the same amount of air the velocity is less; and secondly, because the perimeter of a roadway having a large sectional area is

relatively less than that of a roadway having a small sectional area.

(*b*) *The nearer the Air-way is in Shape to a Circle the better.*—This is because circular roadways have less perimeters or rubbing surfaces than any other form used in mines for a given sectional area.

A circle of 10 ft. diameter has an Area of 78·54 sq. ft. and Perimeter 31·46 ft.

A square of 8·86 ft. side has an Area of 78·54 sq. ft. and Perimeter 35·44 ft.

A rectangle 11·22 × 7 has an Area of 78·54 sq. ft. and Perimeter 36·44 ft.

A rectangle 13·09 × 6 has an Area of 78·54 sq. ft. and Perimeter 38·18 ft.

(*c*) *Splitting the Air.*—Perhaps the most important advantage to be derived from a study of the above principles is that of splitting the air. By this we secure:

1. Shorter routes for the air and consequently less friction.

2. Smaller velocities, there being more air-ways; so less pressure and less power are required for a given quantity of air.

3. Purer air for each district, each getting its air fresh from the shaft instead of from an already polluted area.

4. In the event of an explosion of gas taking place in one district, the other districts are less likely to be disturbed.

From the *laws of friction* the formula $pa = ksv^2$ is also obtained.

Here p = the pressure of the air in lbs. per square foot.

a = the sectional area of the air-way in square feet.

k = the coefficient of friction.

s = extent of rubbing surface exposed to the air current.

v = the velocity of the air in thousands of feet per minute.

The first part of the formula, therefore, is the expression of the total pressure producing ventilation, that is the pressure exerted by a ventilating current on the entire sectional area of the air-way. The second part of the formula expresses the resistance of the air-way, being the unit resistance, multiplied by the rubbing surface and the square of the velocity, and, as has been shown, these two factors of the formula are equal, as the whole of the power applied is absorbed in the resistance of the mine.

From this formula we also get

$$p=\frac{ksv^2}{a};$$

$$a=\frac{ksv^2}{p};$$

$$k=\frac{pa}{sv^2};$$

$$s=\frac{pa}{kv^2};$$

$$v^2=\frac{pa}{ks}.$$

From these formulae any one factor in a calculation may be found if the other three be given, the coefficient k being a constant.

The Distribution of the Air through the Mine.—In order to direct the air current through the mine, it is necessary to do so by artificial means; but as each of such structures is often a source of loss and may become a source of danger, it is necessary not only to have well-erected arrangements, but also to have as few of them as possible. The best ventilated mine is not the one which has the largest number of artificial ventilating arrangements, but the one where most of the ventilation is done naturally, that is, by the number, size, direction and position of the roads themselves.

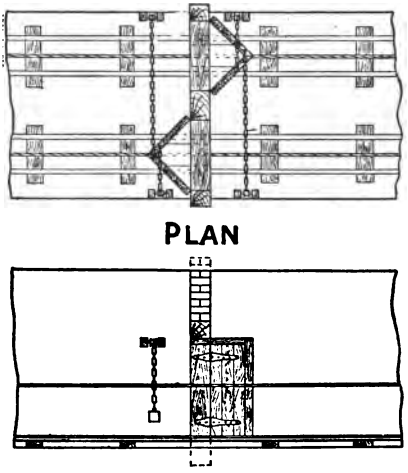
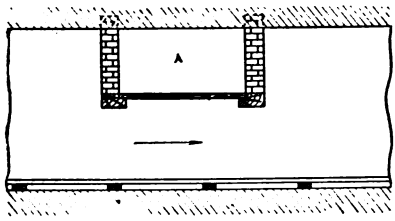


FIG. 160.—Self-Acting Air Doors for Endless Rope Haulage Road.

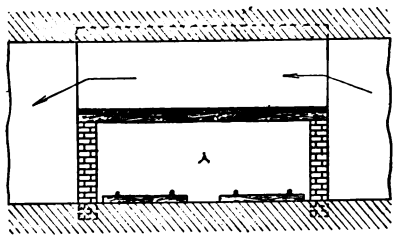
Ventilating Arrangements.—The ventilating arrangements necessary are as follows:

Air Doors (Fig. 160) are for the purpose of turning the whole of

the air. According to the Coal Mines Regulation Act the doors must be made and fixed so as to close of themselves. They are placed in the roadway which connects the upcast and the downcast shafts, and in any other roadways where the air has to be turned completely.



MAIN ROAD ELEVATION.



MAIN ROAD SECTION.

FIG. 161.—Air Crossing.

Screens or Cloths are intended to check the air at that point, or in some cases they are used where an ordinary air-door would be inconvenient.

Air Pipes are used to divide the air-way into two parts for a certain distance, thus causing the air current to pass along one side and return along the other.

Bratticing consists of timber or cloth partitions fixed in a roadway or shaft, and are for the same purpose. **Air Pipes** consist of pipes of wood or iron.

Air Crossings (Fig. 161) are for the purpose of carrying one air current over another; it will easily be seen that unless they are exceedingly well constructed there will be a great loss of air, as the intake air will get into the return current.

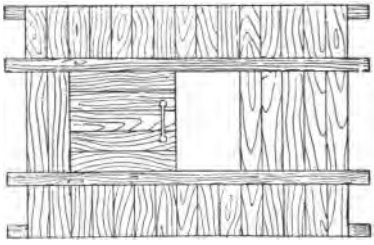


FIG. 162.—Regulator for Air Current.

Stoppings are used to prevent the air current from going in a certain direction, and should be well constructed so as

to be air-tight. They are of bricks or stones or debris from the mine.

Regulators.—A regulator (Fig. 162) is a small door fixed in a frame and set in a ventilating district in such a position as to catch the whole of the air passing through that district. It is for the purpose of regulating the supply of air, and must be kept in such a position as to pass only the exact amount of air apportioned by the manager for that district.

Instruments Used.—The instruments used for registering the ventilation of a mine are: (1) the barometer, (2) the thermometer, (3) the anemometer, (4) the water gauge.

At collieries where much experimenting is done, other instruments are also used, but the above should be in use at every colliery. The General Rules require that the first, second and third shall be used.

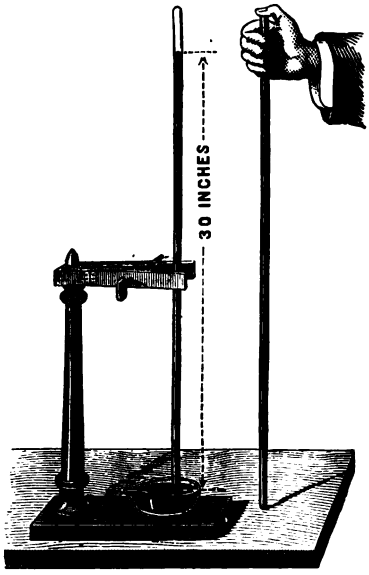


FIG. 163.—Construction of a Barometer.

The Barometer is an instrument for measuring the pressure of the atmosphere (Fig. 163). A narrow glass tube, about 33 inches long, has a column of mercury in it, and stands in a small cistern holding mercury; at the top above the mercury, where the tube is closed, there are a few inches of nearly perfect vacuum. The tube is attached to a board with a small index near the top, marked in inches and tenths of an inch from 28 to 31, which is the average range of the barometric pressure at the sea level. The explanation of the action of the barometer is simple. The top of the column is closed, while the surface of the mercury in the cistern is open to the atmosphere. The

pressure of the atmosphere upon the surface of the mercury in the cistern balances the mercury in the column. The distance between the top of the column and the surface of the mercury in the cistern is generally about 30 inches. If for any reason the weight of the atmosphere becomes greater, the mercury will be pushed higher to preserve the balance; if it should become less, the height of the mercury will be diminished as the amount of mercury which can be supported will be less.

The Thermometer or Temperature Measurer.—One of these instruments, for showing the temperature of the air at any required part of the colliery, is now generally attached to the barometer, which is fixed in a conspicuous place at every colliery in accordance with the law. It is a very simple instrument, consisting of a small column of mercury in a sealed glass tube with a bulb at the bottom, and fixed to a board, upon the face of which are marked degrees of temperature, Fahrenheit or Centigrade, or both, as the case may be (Fig. 164). The range of temperature marked on the one fixed with the barometer need not be very great, as it is always in one place and subject only to such changes as ordinary summers and winters bring; but as the temperature of shafts where furnaces are in use have to be taken, special thermometers must be used for these purposes. As mining engineers and managers do not all adopt the same thermometer, or use the same scale for their calculations, it is well for the student to acquaint himself with both scales and both methods of calculations, *i.e.* the Fahrenheit and the Centigrade. In the former the temperature at which water freezes is indicated by the number 32, which is referred to as 32 degrees or 32°. This is known as the freezing point, and on the same scale the boiling point of water is 212°, thus making the degree the one-hundred-and-eightieth part of the distance between the freezing and boiling points; Zero on the Fahrenheit scale is therefore 32° below the freezing point.

FIG. 164.—A Thermometer.

In the Centigrade scale the freezing point is fixed at Zero, and the rise from freezing point to boiling point is divided into 100 degrees. Thus, a Centigrade degree is exactly the one-hundredth part of the difference of temperature between the freezing and boiling points of water. One degree Centigrade is thus to 1 degree Fahrenheit as 100 is to 180, that is, as 5 is to 9.

With these facts and figures before us, it is quite easy to convert the markings of one scale to those of the other.

To convert Fahrenheit to Centigrade we first deduct 32, then multiply the remainder by 5 and divide by 9.

Take, say, 180° Fahr. ;

$$180-32=148\text{; and } \frac{148\times 5}{9}=\frac{740}{9}=82{\cdot}2^{\circ}\text{ Cent.}$$

Then to convert Centigrade to Fahrenheit we take the opposite course, *i.e.* multiply the degrees Centigrade by 9, divide by 5 and add 32.

Say, 60° Cent. ;

$$\frac{60\times 9}{5}+32=108+32=140^{\circ}\text{ Fahr.}$$

It is the custom in scientific laboratories to use the Centigrade thermometer, but either system of measuring temperature can be adopted in ventilation work.

The Anemometer or Wind Measurer is an instrument used for measuring the velocity of the air current in a mine. In using the anemometer it must be remembered that the current in the mine is liable to variation just as it is on the surface, and the readings should be observed for several minutes, the average speed per minute being carefully ascertained. Also, it must be remembered that a current of air in a roadway is like a stream of water between banks, the water flowing less rapidly at the sides than in the centre, owing to the friction of the water against the banks. When, therefore, an exact measurement is to be made of the velocity of the air current, the anemometer must not be held in the centre of the road only, where it would show the maximum, nor at the top, bottom or side, where it would show the minimum speed. It must either be moved about equally over the whole area, or the roadway must be divided into a number of equal sections, and the instrument held an equal length of time in each section.

When the velocity in feet per minute has been ascertained, the height and width of the air-way are measured, and these multiplied together give the sectional area, which should be reduced to square feet and inches or fraction of a square foot; and this result multiplied by the velocity will give the cubic feet of air going into or returning from the workings per minute at that particular place. Suppose an air-way is 10 feet wide and 6 feet high, that is 60 square feet in sectional area. If the ascertained velocity be 450, we should then have $10 \times 6 \times 450 =$ 27,000 cubic feet of air passing along that road per minute.

Anemometers are made in several forms, the two most common being those of Mr. Joseph Dickenson and of Mr. Biram.

The **Dickenson Anemometer** (Fig. 165) is very simple both in construction and action, and may be said to consist simply of a thin plate of talc or other light material about 4 inches square, representing a door, against which the air current in the roadway presses. This door is suspended from what may be termed the lintel of a brass door frame. To one side of this frame is fixed a quadrant with divisions. The door rests opposite the end of the quadrant when it is vertical, *i.e.* when it is not pressed by the wind. The quadrant is marked in 20's, beginning at 200, and rising to 700 or 800 feet when strongly pressed —in other words, when there is a strong wind.

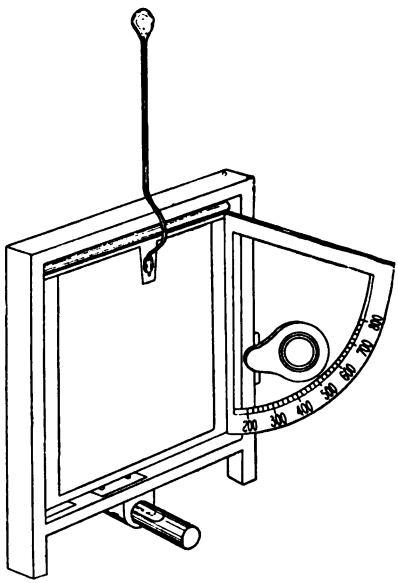


FIG. 165.—Dickenson's Anemometer.

As the door of the anemometer is fixed exactly across the roadway to receive the full force of the wind, it rises or falls as

the current is greater or less, and should be held some little time so as to get its average height—with this instrument there is no need to record the time during which the anemometer has been held. The number on the quadrant which the door stands opposite, represents the distance in feet per minute the air is travelling.

The second of the two forms of anemometer is **Biram's** (Fig. 166). It consists of a number of vanes, similar to those in a windmill, with an arrangement of wheels, by which a finger moves once round a disc whilst a current of 100 feet

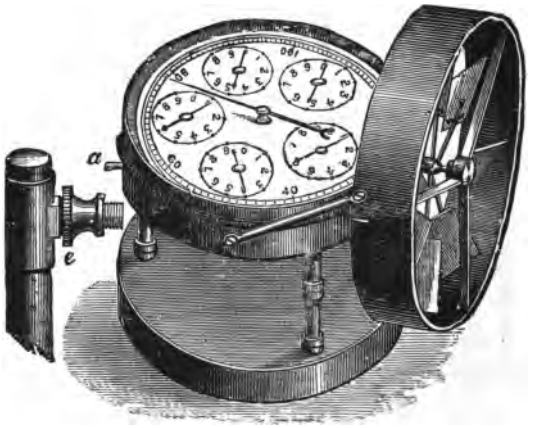


FIG. 166.—Biram's Anemometer.

passes, and a smaller finger moves one division in the same time, exactly as the two fingers of a watch move. In using this instrument, it is necessary to mark the time during which the anemometer is held in the current. The numbers at which the two fingers stand are first read off, a watch is held in readiness, and exactly at a given second the wheels, which, when not in use, are held by a small catch, are released, and at once the two fingers indicating the velocity begin to move.

At the end of *one minute exactly* the numbers at which the fingers stand are again read off, and when the previous reading has been deducted, the difference shows the velocity

in feet at which the air has been travelling during the minute.

It may be here observed that, for greater accuracy and a more trustworthy average rate, the anemometer may be held for several minutes, the total feet passing in the time being divided by the numbers of minutes to get the average.

Water Gauge (Fig. 167).—Whilst the barometer at a mine is used to show the pressure of the atmosphere at the surface, the water gauge is used to measure the difference in pressure in a roadway of a mine or in a drift between the atmosphere on one side of a door and on the other.

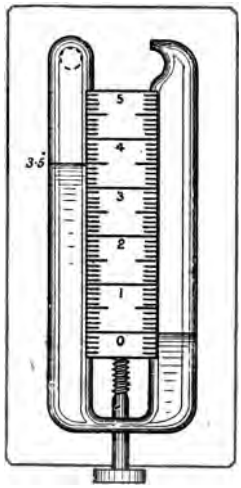


Fig. 167.—Water Gauge.

Where a water gauge is used to indicate the ventilating pressure of a mine, one end of the tube of the water gauge is open to the atmospheric pressure on the intake side of the air-way, *i.e.* as the air is entering the workings; whilst the other end is open to the air as it is coming out, and where a partial vacuum has been created by a fan, furnace or other artificial means.

The gauge itself consists simply of a U-shaped tube, three-eighths of an inch in diameter and six or more inches high, fixed to a board with an index divided into parts of an inch, in such a way as to show "an inch of water gauge" when the water on the downcast or intake side has been pushed down half an inch, and so for any fraction of an inch. Of course when the water in one tube is pushed down to the extent of half an inch, the difference in the two surfaces is then one inch.

It may be here pointed out that while in the barometer the mercury shows the total atmospheric pressure, the water in the water gauge shows only the difference of the pressures of the air against the intake and return sides of the door or wall. And it may be further noted that while the total pressure shown by the barometer represents, on the average, about 29·5

inches of mercury, equal to about 14·7 lbs. pressure per square inch, the difference of pressure shown in the water gauge is only 5·2 lbs. per square foot for each inch of water, *i.e.* each inch of difference in the water levels.

Let us see how it is that 1 inch of water is calculated as 5·2 lbs. per square foot. In the first place, take a cubic foot of water, say a cistern 12 inches square and 12 inches deep. The weight is 62·5 lbs. Now, if we divide the height by 12, we shall have 1 inch in height, and the water in that 1 inch would weigh

$$\frac{62{\cdot}5}{12} = 5{\cdot}2 \text{ lbs.},$$

and as this would be spread over a square foot, we call it a pressure of 5·2 lbs. on the square foot for each inch of water; 2 inches being $5{\cdot}2 \times 2 = 10{\cdot}4$ lbs., and so on until, if we could get a 12-inch water gauge, we should have $5{\cdot}2 \times 12 = 62{\cdot}5$ lbs. per square foot.

Suppose the pressure on a water gauge is 2 inches, what is the pressure per square foot?

$$2 \times 5{\cdot}2 = 10{\cdot}4 \text{ lbs.}$$

Suppose in this case the air-way were 9 feet wide and 7 feet high, what would be the total pressure on the door?

$$9 \times 7 \times 10{\cdot}4 = 655{\cdot}2 \text{ lbs.}$$

Calculations.—It has been seen that the pressure required to produce a double quantity of air along a given road in a certain time would be fourfold, but the power required would be eight times as much, that is, whilst the pressure increases as the square of the velocity, the power increases as its cube.

1. If a pressure of 5 lbs. per square foot be required to force 30,000 cubic feet of air per minute through an air-way, what would be the air horse-power?

$$\frac{30000 \times 5}{33000} = 4{\cdot}545 \text{ horse-power.}$$

2. If, instead of 30,000 cubic feet in the last example, we wanted 60,000 cubic feet of air, what would be the pressure and the horse-power?

$$\text{Pressure} = \frac{60^2}{30^2} \times 5 \text{ lbs.} = 20 \text{ lbs., or 4 times the original pressure.}$$

$$\text{And horse-power} = \frac{60000 \times 20}{33000} = 36{\cdot}36, \text{ or 8 times the original horse-power.}$$

3. Suppose, again, the quantity had to be trebled, *i.e.* raised to 90,000, what would be the pressure and the horse-power?

$$\text{Pressure} = \frac{90^2}{30^2} \times 5 \text{ lbs.} = 45 \text{ lbs.}, \text{ or 9 times the original pressure.}$$

$$\text{And horse-power} = \frac{90000 \times 45}{33000} = 122{\cdot}727, \text{ or 27 times the original horse-power.}$$

Questions on Chapter XIII.

1. What are the various causes of the pollution of the air of mines?

2. In a deep and fiery mine what amount of air per minute do you consider requisite for each person employed? When would you consider a mine adequately ventilated?

3. Explain the terms, rubbing surface, area, perimeter and section of an air-way, and determine them for a rectangular level, 6 by 7 feet, and 500 yards long. (1894.)

4. What are the four principal factors influencing the circulation of the air current through the mine, and upon which the quantity of air circulating depends?

5. What is meant by splitting and regulating air currents? (1894.)

6. A certain amount of air is passing through an air-way. What increase of power would be required in order to pass 25 per cent. more air through the same air-way?

7. What practical points arise from the three laws of friction?

8. What is meant by pressure producing ventilation and the power producing ventilation?

9. During an explosion the brattices, doors, regulators, air crossings and fan are liable to get deranged and damaged. How would you guard against this in each case?

10. Explain the uses of the barometer, thermometer, anemometer and water gauge in controlling the ventilation of mines. (1896.)

CHAPTER XIV.

PRODUCTION OF AIR CURRENT.

It has already been explained that in order to cause a current of air to flow through the shafts, roadways and workings of a mine, a difference in the pressure of the air in the two shafts must be established.

This difference of pressure may be brought about either naturally or artificially; but it must be borne in mind that, however accomplished, the ventilating pressure thus obtained must be sufficient to overcome the resistance which the air will inevitably meet immediately it begins to move. The power required to set the air in motion is so slight that in all calculations it is only necessary to take into account the resistances set up by the shafts, roadways and workings of the mine; and therefore the record of the amount of work expended in driving the air through the mine is also a record of the amount of resistance offered by the passages of the mine to the current; that is to say, the whole power of the air is absorbed in friction.

Natural Ventilation.—By natural ventilation is meant that which arises from atmospheric conditions, the burning of lamps and candles, the breathing of men and animals, and similar causes, without applying any aids to ventilation. Suppose a level tunnel AB driven through a hill, the pressure of the atmosphere would be the same at A as at B, and there would be no tendency to motion of the air. If men were at work, the air in the tunnel would probably be warmer in winter than that outside, but cooler in summer. Still there might be no movement, or, if there were, it might depend upon the direction of the wind outside. Or, again, suppose

there are two pits, *A* and *B*. If the depths of the two shafts vary greatly, the one, *A*, being on a hill, the other, *B*, in a valley, the shaft on the hill would probably be the upcast in winter and the downcast in summer if the movements of the air were left to natural ventilation alone; the column of air from the top of the shaft *B* to the level of the shaft *A* would probably be colder than that in *A* in winter, and therefore heavier, and the reverse in the summer. Hence the ventilating current would change as wind or season changed, and if a small furnace were lighted at the bottom of one shaft, there would be the danger of a change of wind carrying the smoke into the workings, so that there is no reliance to be placed on natural ventilation, especially for extensive workings. Only apparatus of considerable power can be relied on for setting and keeping a sufficient body of air in motion and in the desired direction.

Furnaces are simply large fires placed near the bottom of the upcast shaft in some mines for raising the temperature of the air in that shaft. In the arrangement of the bars, and in the building of the supporting and surrounding walls, certain leading principles should be observed, as follows:

1. Sufficient fire-bar area.
2. Sufficient distance between furnace and shaft.
3. Sufficient fresh-air space between furnace arch and outer arch to keep the walls of coal and other strata cool, and an outer arch backed by some non-conducting substance.
4. Arrangements to include the keeping of all **return air**, that is, air which has been through the workings and is returning to upcast shaft, entirely away from the furnace and its approaches, and to admit air only direct from the downcast.
5. There should also be means for regulating the quantity of air to go over the furnace at any and all times, and the air before entering the furnace should be made to course along the outer walls so as to cool them.

In order to have plenty of fire-bar area, the best plan is to have the furnace fired at the sides (Fig. 168). It is then simply a question of making the furnace long enough. This method is also convenient for the furnaceman, as he can have his coal quite near to the place where it is to be thrown on, and he can be well sheltered from the cold current when not compelled to be at work.

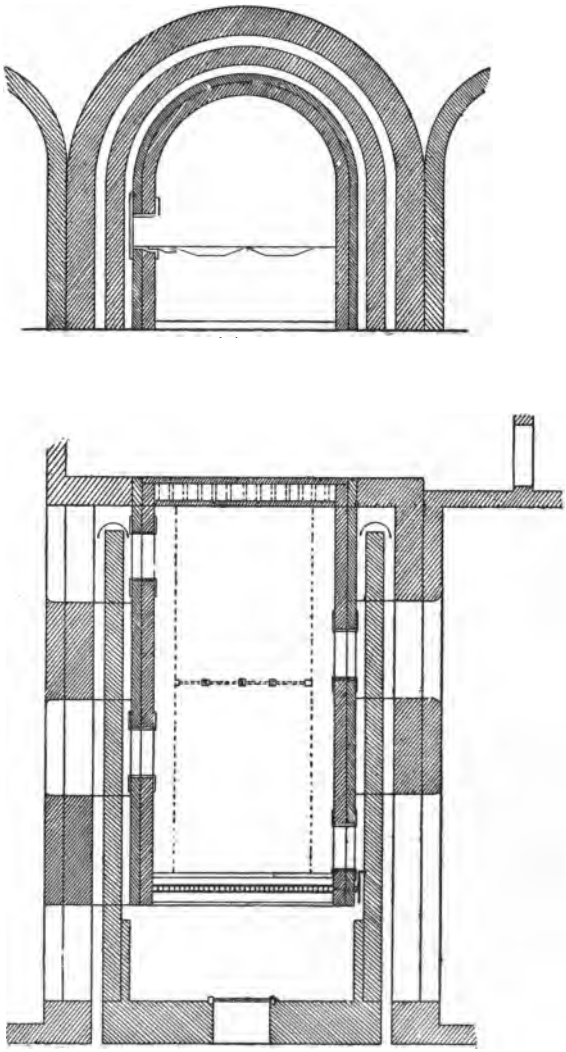


Fig. 168.—Section and Plan of Furnace.

Mechanical Ventilators.—There are various kinds of mechanical ventilators, most of which are on the centrifugal principle. A few air pumps or displacement machines have at various times been tried, but they are so little used for mine ventilation now that they will not be described here.

Centrifugal Fans.—When a fan is revolved, a centrifugal force is developed by the revolution of the air between the blades, causing the air to rush towards the circumference. This creates a **depression**—reduction in the pressure of the air (or partial vacuum)—at the centre of the fan, and causes a further supply of air to enter the fan. But it must also be remembered that this centrifugal force causes a **compression** or increase in the pressure of the air at the tips of the blades, corresponding to the amount of depression at the centre. It will thus be seen that centrifugal fans may be used either as **exhaust** or **force fans.** If a fan of this kind is required to act as an exhaust fan, it is only necessary that its inlet should be placed in connection with the air-ways of the mine and the outlet be open to the atmosphere. When, therefore, a depression or reduction of the pressure of the air is caused by the rotation of the fan, the atmospheric pressure at the downcast shaft will force the air through the mine and through the fan. If it is desired to use the fan as a force fan, then its outlet must be placed in connection with the air-ways of the mine and its inlet left open to the atmosphere. The compression or increase in the pressure of the air at the tips of the fan blades will then force the air through the mine and out at the top of the upcast shaft. If the fan in either of the above cases is placed on the surface, it is necessary to cover the top of the shaft with closing doors to prevent surface air from entering the fan in the case of an exhaust or to prevent air escaping to the surface in the case of a force fan. In either case the fan is connected to the shaft by a suitable passage called the **fan drift** (see Fig. 159). This passage must be so placed and constructed as to assist in avoiding accidents to the fan, and it may be here noticed that in regard to the placing of the fan, the Coal Mines Regulation Act requires:—"General Rule 3—Where a mechanical contrivance for ventilation is introduced into any mine after the passing of this Act, it shall be in such position and placed under such conditions as will tend to its being uninjured by an explosion." In the case of extensive

workings, it may be an advantage to have other fans placed at suitable points in the mine.

Preliminary Considerations.—Before proceeding to describe the various types of fans, it is necessary to define a few important terms which will be continually referred to, viz., Equivalent Orifice, Mechanical Efficiency, and Manometrical Efficiency.

Equivalent Orifice.—M. Murgue, a French mining engineer, refers to the **Equivalent Orifice** as an opening in a thin plate which represents the resistance met with in the mine; that is to say, the area of the orifice or opening in the plate in passing a certain amount of air causes a water-gauge pressure which is equal to the water gauge produced by the passage of the same amount of air through the workings of the mine.

It will be clear that, if a fan is run at its top speed unconnected with the mine, and with the inlet entirely closed, the difference in pressure of the air inside and outside the fan will be the greatest possible for that fan; that is to say, we shall obtain the largest possible water gauge, because we discharge practically the whole of the air from the fan without readmitting any. If the area of inlet is as great as possible, the difference in pressure of the air inside and outside the fan will be the smallest possible for that fan; that is to say, we shall obtain the least possible water gauge, because we admit more air in proportion to the amount the fan discharges, the water gauge in this case being absorbed in the resistances within the fan itself. Between these highest and lowest water gauges will be a water gauge produced when the inlet is connected with the workings of the mine. This area of inlet is called the **equivalent orifice.** The size of this opening can be obtained by dividing the square root of the water gauge into the quantity of air in thousands of cubic feet per minute multiplied by 0·38, thus:

$$EO = \frac{0{\cdot}38\,Q}{\sqrt{w.g.}}.$$

Hanarte's Theory.—M. Hanarte differs from M. Murgue in his reasoning, pointing out that the latter has not allowed for the difference in the proportion of perimeter to area in a large or small opening. We have already shown that the ratio of perimeter to area is much greater in a small road than a large one. M. Hanarte consequently prefers to compare the resistance met

with in one mine with that of another, according to the volume of air per second which a mine would pass at a standard water gauge, say of 1 in.

The **Mechanical Efficiency** of a ventilator is the ratio of the useful work performed per second to the work done upon the shaft of the machine per second. This is a most important feature in a fan, as it must be clear that whatever the output of the fan, the power supplied to drive it must be used up as efficiently as practicable; that is to say, there must be no loss of power between the engine and the fan.

The **Manometrical Efficiency** is the Water Gauge Efficiency, and may be taken as the ratio between the actual Water Gauge equivalent of the air of the mine and the theoretical Water Gauge equivalent determined from the capabilities of the fan and the equivalent orifice of the mine.

Mine Fans may be divided as follows:

1. Open-running Fans.
2. Large Enclosed Fans.
3. Small Quick-running Enclosed Fans.
4. Small Open-running Fans.

Open-running Fans.—The **Waddle** is the chief representative of this class. It has been in use for a great number of years, and is capable of transmitting large volumes of air. The advocates of open-running fans contend that this method of producing an air current is advisable, as there is no opposition to the free passage of the air as is the case with enclosed fans. It is contended that if the air is allowed to pass from the fan all round the circumference or periphery less power is required in the engine, and a higher efficiency of the fan is obtained.

Large Enclosed Fans.—The following fans may be placed in this class:

(*a*) The Guibal.
(*b*) The Walker.
(*c*) The Cockson.

These fans are made in various sizes up to 30 or 40 feet diameter, and are either **Single** or **Double Inlet**, that is to say, the air may be allowed to enter on one side or on both sides of the fan. These fans are usually driven by ropes or straps, but may be driven direct. They are run in casings made to suit

the fan, and the casing ends in a gradually expanding chimney called an Evasee chimney, which reduces the velocity of the air as it leaves the fan vanes and enters the atmosphere. The velocity at which the air leaves the vanes is considerable, and the advocates of this type contend that this velocity represents energy of motion, which can only be utilised to help the fan in case the latter is enclosed and provided with an expanding chimney, by means of which this energy of motion may be converted into pressure.

Small Quick-running Enclosed Fans.—In this class we may include the following:

(*a*) The Schiele.
(*b*) The Capell.
(*c*) The Rateau.
(*d*) The Ser.
(*e*) The Sirocco.

These fans, varying in diameter from 3 to 15 feet, are run at high velocities, and consequently, although they discharge a smaller amount of air at each revolution than the large fans, their high speed enables them to transmit large quantities per minute. The great advantages of small fans are:

(1) That they require little or no foundations.

(2) That the engines for running them are smaller and require less steam.

(3) That the speed can be varied more economically to suit the requirements of the mine.

(4) That the fan can be run for temporary periods at exceedingly high velocities without danger of damaging the bearings, etc.

(5) That one or more fans may be used as required, the system therefore being more elastic, and this in extensive mines is often necessary.

Small Open-running Fans.—Parsons' Turbo-Fan is the chief representative of this class. It is not open-running in the sense that the Waddle is, but it is placed directly in the way of the current, and as it is provided with no close-fitting spiral casing, and gains nothing from the application of an Evasee chimney, it may be said to be open-running. Here high speed and great efficiency of the driving compensate for what the fan loses in the above respects.

The Waddle.—As already stated, this is the chief representative of the "open-running" fans. It is now forty years since the first Waddle fan was set up, and this, although running regularly at 100 revolutions per minute, is still doing good work. In construction the Waddle fan may be considered as a light, hollow disc, the two sides of which are strongly braced together by the blades. The periphery is open all round, and the air is discharged equally from every part of it. The load on every blade and on every part of the fan is

FIG. 169.—Waddle Fan.

therefore steady and unvarying, so that there is a complete absence of the vibration generally found in the large enclosed fans. This absence of vibration not only lengthens the life of the fan, but it enables it to be run at a much higher speed than would otherwise be possible. The air enters at one side of the fan only. The fans are driven direct, though in some cases ropes are used. The makers, however, do not recommend this latter method, contending that rope driving not only entails a considerable loss of power through friction, but increases the wear and tear and liability to breakdown, as well as necessitating additional expenditure on masonry for foundations. The blades are **radial**, that is, are connected directly to the centre shaft of the fan and curved with the convex side

in the direction of rotation; they are alternately long and short. The discs incline towards each other. One of the most important improvements recently made in the fan is the patent outlet, which delivers the air to the outer atmosphere at a greatly reduced speed, a great portion of the energy formerly wasted being thus restored before the air leaves the fan.

The outlet has trumpet-shaped sides, gradually enlarging from the tips of the blades, the area of opening at the edge of the outlet being twice as much as the area at the tips of the blades. Experiments made with and without the outlet show that the outlet greatly increases the mechanical efficiency of the fan, and increases the volume by over 20 per cent. In Fig. 169 is shown a Waddle patent self-contained fan and engine, the fan being provided with the new form of V-shaped outlet. The fan is 9 ft. in diameter to the tips of the blades, and is capable of circulating 80,000 cubic feet of air per minute at 2-in. water gauge, viz., 10·4 lbs. One massive bed-plate is provided for both fan and engine. The fan inlet may be connected to the covering over the upcast shaft by means of a wrought-iron tube, so that it is unnecessary to build a fan drift. The advantages of this mode of construction are that the usual fan-drift bearing, so difficult as a rule to get at, is not required, and as there is no pedestal or wall at the inlet of the fan, the flow of air into it is unimpeded. These self-contained fans are now taking the place of the larger ones, being made in sizes up to 25 ft. diameter for volumes up to 350,000 cubic feet, and water gauge pressures up to 10 in. The engines are made high pressure or compound according to the amount of steam available and the work to be done. A Waddle self-contained fan, 21 ft. diameter, recently erected to replace a 40-ft. fan of the old type, and in a mine having a small equivalent orifice, shows the following results: Volume, 110,200 cubic feet; revolutions, 168; water gauge equivalent, 7·4 inches, viz., 38·48 lbs.

As an example of a self-contained fan of the same size at a mine with large equivalent orifices, the following results may be given: 21-ft. Waddle patent self-contained fan, at 116 revolutions per minute, gives 303,000 cubic feet per minute with 2·2 inches water gauge equivalent, viz., 11·44 lbs.

The Guibal.—This fan has straight blades, not arranged radially, and runs in a casing very slightly larger than the fan. Its chief features are as follows: Straight blades, eight or ten in number, each secured to bars and angle irons, the latter bolted to cast-iron bosses, and keyed on to the shaft. Single or double inlet. Large diameters up to 40 feet or more are provided with a regulating shutter at the point where the air leaves the tips of the blades and enters into the chimney, this being adjusted, as required, to prevent vibration, otherwise caused owing to the orifice being too large or too small; and an expanding or Evasee chimney, which serves to reduce the velocity of the current before it enters the outer atmosphere.

The Walker.—The Walker "Indestructible" fan (Fig. 170) is a modification of the Guibal. Unlike the Guibal, however, it is placed eccentrically in a volute or spiral casing, and the blades, which are curved slightly backwards, are radial blades, being secured to a central disc instead of to arms. The fans are generally double inlet, and are made in various sizes up to 30 ft. diameter.

The main bearings of the fan are placed in the two inlets of the fan chamber, the distance inside the bearings being little more than the width of the fan, the outer bearing being placed just outside the rope pulley upon the fan shaft. The pedestals are cased all round to prevent access of dust to the bearings. It is very necessary to minimise the slipping of the air between the sides of the vanes and the walls of the fan-chamber as far as practicable. The vanes being strong, and of iron, cannot be brought close to the walls, as in the event of any side movement of the fan on its bearings the vanes might "catch" and be injured. This clearance is therefore made up by attaching strips of pliable hoop-iron to the sides of the vanes.

The Walker Anti-Vibration Shutter.—This arrangement, which is used also for other fans, consists of a shutter or slide in the form of an inverted "V" placed at the point where the air leaves the vanes and enters the chimney. Instead of being fixed parallel with the axis of the fan, the lower edge is inclined. This "V" shutter has the effect of greatly reducing the vibration caused where it is not used, by the too abrupt cessation of the delivery of the air from the fan vanes or blades as

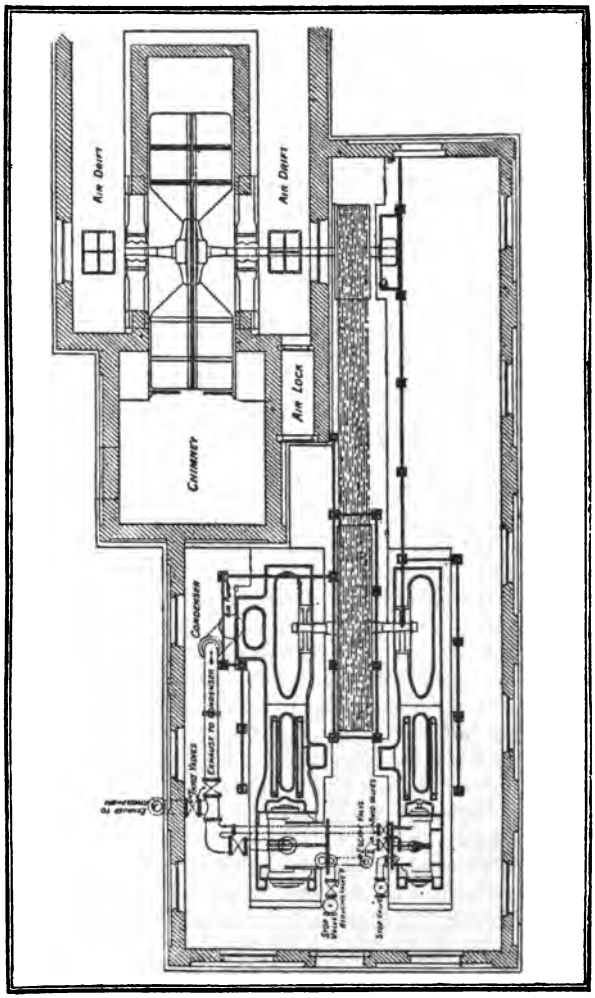


Fig. 170.—The Walker "Indestructible" Fan.

they pass the opening to the chimney. Ordinarily, the upper part of the opening in the slide has a line parallel to the tips of the fan blades, and as the fan revolves the delivery of the air is suddenly terminated. The pressure of air upon the blades is thus alternately great and small, the vacuum formed within the casing having the effect of suddenly removing the load on the blades, which rebound upwards at the next instant. This rebound produces great vibration, and ultimately a great shock upon the whole of the fan and the fan shaft. This evil is removed by using the inverted "V" shutter. It effects a perfectly gradual change in the pressure referred to, and so governs the discharge of the air as to cause it to pass without eddies in a continuous stream from the fan blades into the chimney, instead of intermittently, and with the pulsatory effect described. The shutter is constructed in sections, any of which can be removed for the purpose of adapting the area of the opening to the work the fan has to do.

The Capell Fan (Fig. 171).—These small, quick-running fans are made both with single and double inlets. They have two sets of vanes, an inner and an outer set. The air on entering the fan at either side is received into a cylindrical chamber containing blades projecting inwards, and curved with the convex side in the direction of rotation. The air, in consequence of the vacuum created by the revolving wings, is discharged through a series of portholes in the cylinder, one porthole being placed between each pair of wings. Passing outward through the portholes at a high velocity, the air is discharged against the inner and concave side of the outer wings, the result being that while a large portion of its **vis viva**, as the force inherent in the air is termed, is taken up by the revolving outer wings, the velocity of the issuing air is greatly reduced on account of its entrance into the much larger chamber contained between the cylinder and the outer wing. From the tips of the outer wings the air is discharged into the gradually increasing spiral casing called the **fan-race**, and then passes by means of the Evasee chimney into the open air at a still further reduced speed. The latest design of Capell fan has scoops on the inner wings. The scoops have their greatest projections near the centre; the ends near the outer edge of the inlet are placed inside the fan, and deliver

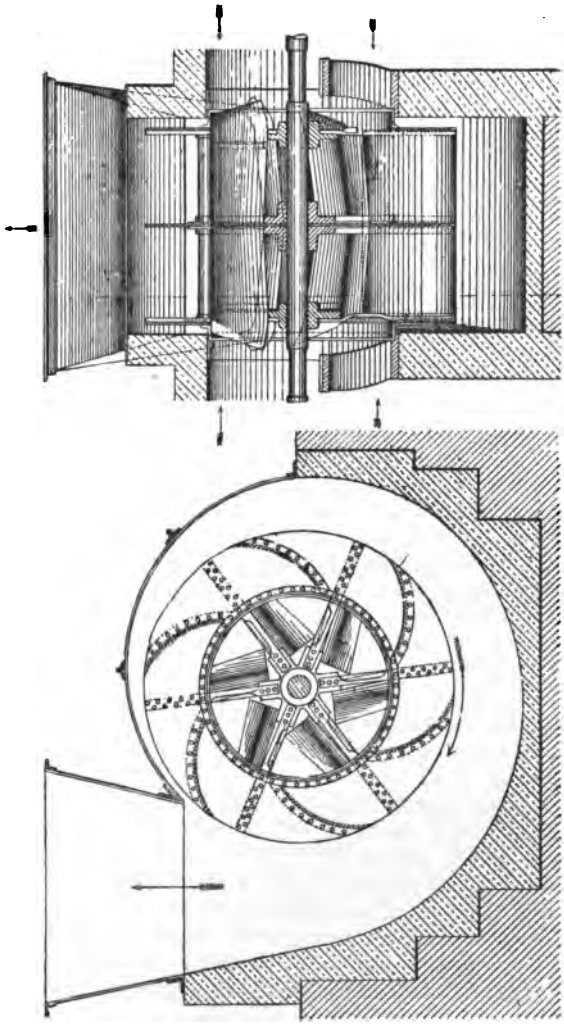


Fig. 171.—The Capell Fan.

the air between the wings. They add considerably to the fan's power of transmitting air. Extremely large water gauge equivalents have been obtained on the Continent and in America by these fans. At the General Blumenthal Colliery, Germany, a Capell fan, 13 ft. 6 in. by 6 ft. wide, double inlet, passes 227,000 cubic feet per minute at 12·5 in. water gauge equivalent, viz., 65·00 lbs.

Single inlet fans are sometimes used for quantities up to 250,000 cubic feet per minute, and for these, high-speed engines are used running up to 180 revolutions per minute. The fans—whether single or double inlet—are invariably driven by ropes.

Electrically-driven fans of this type, to the number of about fifty, are now in use for ventilating coal mines. The largest electrically-driven fan is 16 ft. × 10 ft., giving 490,000 cubic feet at 120 revolutions per minute.

The Rateau Fan.—In this fan a turbine or fan wheel, provided with a number of fixed vanes of special form, is attached to a cone-shaped casting, which is caused to rotate rapidly at the end of the fan shaft. The blades, which vary in number from 24 to 30, have each four edges, and are curved in the direction of rotation, forming as it were an elaborate series of scoops, referred to in the case of the Capell fan. A hood, which overhangs the vanes, guides the air through the fan inlet, and after passing through the fan into the spiral casing is discharged in the usual way through a gradually-expanding chimney, which, however, is larger than the usual Evasee chimney. The fan is made in various sizes up to 10 ft. diameter, and, being run at a high velocity, is capable of passing large volumes of air.

The Parsons Turbo-Fan.—In 1894, Messrs. C. A. Parsons & Co. undertook a series of exhaustive experiments with a view to develop a type of fan suitable for use in conjunction with their well-known compound steam turbine. The fan is arranged in the neck of a double-coned tube (Fig. 172), which allows the air to approach and leave the fan without serious loss from shocks; and it has been found that with a properly-proportioned propeller and cone, high efficiencies are obtainable. From its special construction, the turbine can be placed in an atmosphere laden with coal dust, etc., without taking harm. It is therefore particularly adapted for driving colliery fans, and

its comparatively high speed enables the size of the fan to be kept very small. The fan bearings are lubricated in the same manner as the turbine bearings and by the same oil pump. The combination of such a fan with a steam turbine makes an extremely compact and efficient ventilating plant; it requires little foundation and small outlay for erection, buildings, etc., while the perfectly automatic governing and lubrication of the turbine reduce the amount of attention to a minimum. The engine can be run for lengthened periods without needing to be stopped for adjustment or repairs. The following results

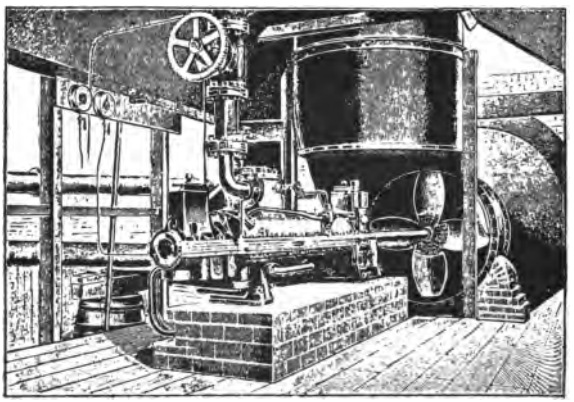


FIG. 172.—The Parsons Turbo-Fan.

have been obtained by this fan: At Clara Vale Colliery, Wylam-on-Tyne, a screw fan, driven direct by Parsons' steam turbine, exhausts air from the pit and discharges it into the atmosphere through a conical outlet. The diameter of the fan is 5 ft., and it passes 120,000 cubic feet per minute at 2 in. water gauge, running at a speed of 2,000 revs. per minute. The steam pressure at the turbine is 70 lbs. per square inch, and the exhaust steam is condensed.

At Marley Hill Colliery, Durham, a screw fan blows air through the mine instead of drawing it out. The fan is 3 ft. diameter, and passes 36,000 cubic feet at 1½ in. water gauge equivalent, viz., 6·5 lbs., at a speed of 2,500 revolutions. The steam pressure at the turbine is only 19 lbs. per square inch.

At the Hulton Colliery Co.'s Deep Arley Pit, with which the author is connected, a turbine-driven fan has recently been erected. The installation consists of a Parsons' compound steam turbine of the condensing type, coupled at one end to a screw propeller fan 3 ft. 6 in. diameter, and at the other end coupled direct to a two-pole dynamo of 50 Kilowatt capacity. The fan is eight-bladed and made of manganese bronze. It is fitted with wrought-iron discharge cone and bends, and revolves at the rate of 3,000 to 3,500 revolutions per minute. Its estimated output at the higher speed is 80,000 cubic feet at 6 in. water gauge equivalent, viz., 31·2 lbs. The bearings of the turbine, fan and generator are automatically lubricated, the oil being circulated by means of a small reciprocating pump worm-geared from the turbine shaft. Careful tests show that the fan transmits, under the ordinary conditions of the mine, 112,000 cubic feet of air per minute at 5·177 inches water gauge equivalent, at a speed of 3,360 revolutions, the horse-power in the air being 98·2. The steam pressure is 147 lbs. per square inch, and exhaust steam is dealt with by a Ledward's ejector condenser. The efficiency of the fan varies from 50% to 60% according to the conditions existing.

A series of tests have been made on this plant, and it is found that, although this fan efficiency is low compared with that claimed by the majority of fan makers, the efficiency of the steam turbine is remarkably high, and the overall economy of the plant (*i.e.* steam consumed per useful air horse-power output) compares favourably with that usually obtained with centrifugal fans driven by high-class reciprocating steam engines.

The Sirocco Fan.—Few fans are so suitable for high speeds and for electric driving as the Sirocco. These fans were probably intended, when first introduced, for handling only comparatively small volumes of air where the resistance is not great. But experience has shown that they are capable of passing large volumes of air, their peculiar construction enabling them to give a greater output of air per revolution than most cased fans of similar sizes. Their great suitability for electric driving, either from direct-coupled motors or by means of ropes or belt, and the ease with which the speed can be increased and consequently the output greatly enhanced are no mean advantages in their favour.

The chief points in the special construction of Sirocco centrifugal fans (Fig. 173) may be named as follows: The blades are very numerous, with their radial measurement (relatively to the diameter of the fan) very shallow, and their axial measurement very long. Their outer edges are curved forward in the direction of rotation, and the air passages between the blades are usually open at the ends toward the inflowing air. The inlet for admitting the air to the fan, and the outlet for its discharge, are approximately of equal diameter to that of the fan itself. All these features constitute practically a reversal of previous theory and practice in regard to fan construction.

FIG. 173.—The Sirocco Fan.

The inlet and discharge openings being relatively to the fan diameter about four times larger in area than in an ordinary fan, the frictional resistance to the passage of a given volume of air per minute through the Sirocco is therefore only one sixteenth that of other fans; thus, so far as fan resistance is concerned, a higher efficiency in actual work done for the power applied is obtained. The velocity of air into the inlet opening of the fan is almost equal over the whole area of the intake. The construction of the blades obviates the formation of eddies of air near the inlet, as the peripheral speed of the inner edges of the blades being only slightly less than that of the outer edges, the difference between the diameters of the respective circles is unusually small. It is well known that these internal eddies give rise to considerable noise with high velocities, but the Sirocco is almost a silent fan, even at high speeds.

Questions on Chapter XIV.

1. What are the disadvantages of natural ventilation? Give the reasons why it is insufficient in many cases. (1902.)

2. Draw a ventilating furnace and explain the reasons why ventilating furnaces are gradually going out of use. (1902.)

3. Explain the terms "mechanical efficiency," "manometrical efficiency" and "equivalent orifice" used in connection with the ventilation of mines. Show how they are calculated. What is the standard for classifying mines which has been proposed by Hanarte in place of the "equivalent orifice"? (1902.)

4. Describe the construction and mode of action of a centrifugal ventilator with vanes revolving within a fixed spiral casing provided with an Evasee chimney. Show where the air enters and leaves the casing and where the region of lowest pressure in the whole ventilating circuit is to be found.

5. Describe and compare the Guibal and Waddle fans. (1894.)

6. In developing a mine of large capacity, describe what method of ventilation you would adopt. What conditions and considerations would guide you in conducting and making a proper distribution of the total volume of air?

7. Describe and sketch the Sirocco mine fan.

8. Describe and sketch any small quick-running fan with which you are acquainted, and state what advantage this type of fan possesses.

9. What are the principal points to be observed in selecting a fan for ventilating purposes?

10. Name the advantages and disadvantages of large and small diameter fans.

CHAPTER XV.

MINE GASES.

MINES contain a number of gases of a dangerous character, consequent either upon their inflammable properties or upon their depressing or suffocating effects upon the workmen. The danger of these gases is, of course, largely dependent upon the relative quantities which may be present in the air, and accordingly it is altogether necessary that the quantities should be reduced to a minimum by securing a constant and sufficient supply of fresh air.

The production of these dangerous gases takes place, as we have already said, in different ways. Some are formed by the slow combustion which goes on in the goafs (p. 125) and in the abandoned portions of the workings. Others are given off by the coal or other strata immediately above or below the seam.

The Transpiration of Gases.—Most seams, as is well known, give off more or less gas, which has been caused by the changes produced in the vegetable remains forming the coal. Pent up in the seams, the gases often exert great pressure, and strive to make their way out, and when the face of the coal is laid bare, or exposed, the gases more or less gradually make their escape.

This process is called **Transpiration**, and it is by this means that firedamp makes its way into the workings. Some idea of the prevalence of these occluded or enclosed gases may be formed from the fact that they are always present in recently raised coal.

Diffusion of Gases.—If two bottles containing gases which do not act chemically on each other at common temperatures

are connected by a tube and left for some time, the gases will be found to be mixed uniformly, even though they may differ in density or specific gravity. If one bottle be placed above the other, and the heavier gas placed in the lower, they will be found to have mixed after a time, but the length of time occupied will depend upon the density of each. The relation between the density of the gas and the rapidity of the diffusion is expressed thus: *The rate of diffusion varies inversely as the square root of the density of the gas.* It is this property of diffusion which causes firedamp and other gases to become exceedingly dangerous on account of their mixture with the air. Let us imagine that a **feeder** of firedamp is issuing from a cavity in the roof or top of the roadway of a mine. This gas, being lighter than air, would, in obedience to the law of gravity, form a thin layer near the roof, which causes the heavier gas to exchange position with the lighter by downward displacement. But in addition to the exchange of places which is effected by the force of gravity, another movement is always going on. The molecules of gases are never at rest, but are constantly moving about in straight lines in all directions. In consequence of this molecular movement, a gradual mixing of the air and gas takes place, but as the heavier molecules move more slowly than the lighter ones, the rate at which the mixture will become complete will be affected by the force of gravity, and the rates of diffusion of the gases will, as before stated, be inversely proportional to the square roots of their densities. In the case of firedamp and air the proportion may be expressed thus:

$$1 : \sqrt{\frac{1}{0{\cdot}559}} = 1 : 1{\cdot}337.$$

The air and firedamp pass into each other in the proportion of 1,000 to 1,337, and this rule will always hold good. If the diffusion of gases always takes place, it may be asked whence come the large **accumulations of firedamp** (or of blackdamp) which so often occur? These accumulations are possible, owing to the fact that the diffusion in all cases takes place slowly, and such a large amount of gas may be disengaged from the face of the goafs that there is a large surplus still left awaiting diffusion into the air. The rapidly moving air

current, however, disturbs the accumulations of gas near the roof and floor, carrying them along with it, and thus securing a more rapid diffusion than would otherwise take place.

Firedamp.—Also called Carburetted Hydrogen, Methane, Marsh Gas. Symbol, CH_4; molecular weight or density, 8; specific gravity, 0·559; burns with an extremely pale blue flame; is colourless, and, when pure, without smell.

Firedamp consists entirely of methane or carburetted hydrogen, CH_4, but there may be a very few cases in which traces of other hydro-carbons may be found, with carbonic oxide, nitrogen and oxygen. Methane, or marsh gas, is produced in the decomposition of vegetable matter under water, and is given off from the mud of stagnant pools when disturbed. It is given off from seams of coal, as these represent vegetable matter which has become transformed, and has been acted upon during enormous periods of time by heat and pressure. This gas makes its way into the breaks, joints and faults of the adjacent strata, and is there pent up until relieved by the advancing workings, when it quickly makes its escape, in many cases bursting out with terrific force and dislodging large bodies of rock or coal.

Carbon Dioxide.—Also called Chokedamp and Carbonic Acid Gas. Symbol, CO_2; density, 22; specific gravity, 1·524; non-inflammable and colourless, but has a pungent taste and odour.

Carbon dioxide is always present in mines, being produced when coal or other forms of carbon are burnt in the air. It is thus produced owing to the burning of lamps, the oxidation of organic matter in the goafs, by explosions of gas and in the firing of explosives. It is also given off by the breathing of men and horses. Carbon dioxide is dangerous to breathe, as it produces asphyxiation, *i.e.* suffocation, owing to lack of oxygen. If 0·1 per cent. of this gas is present, and is breathed for a considerable time, it will cause discomfort; 10 per cent. is dangerous, and will ultimately cause death; and 20 per cent. will quickly cause death. Lamps are extinguished with 14 per cent. present. As the air exhaled by human beings contains between 3 and 5 per cent. of CO_2, it is readily seen that large volumes of pure air must be constantly available, not only to dilute this gas, but to

replenish the supply of oxygen and decrease the excess of nitrogen.

Blackdamp.—This gas may be recognised by the fact that it causes lights to burn feebly, and eventually to go out. It is composed chiefly of nitrogen,[1] with certain quantities of carbon dioxide. Its effect on men and lamps is similar, in some respects, to that of carbon dioxide, owing to the absence of oxygen. It is generally heavier than air, though not always. Dr. Haldane describes it as the residual gas, resulting from the action of air on oxidisable material present in coal and other materials.

Carbon Monoxide.—Also called Carbonic Oxide and Whitedamp. Symbol, CO; density, 14; specific gravity, 0·97; burns with a beautiful pale blue flame; is colourless, but has a delicate odour.

Carbon monoxide is produced chiefly in mines by incomplete combustion during shot-firing, or owing to the burning of organic matter in the goafs, etc., where there is an insufficient supply of oxygen. It is produced also, in some cases, owing to an excess of carbon, and as both these conditions often occur in the mines, its presence may be expected therein. Although so similar to carbon dioxide in its composition, it is quite different in its properties and effects. Carbon dioxide will not burn, but carbon monoxide burns, and, mixed in certain proportions with the air, forms an explosive mixture. Carbon dioxide is heavier than air and may be looked for near the floor, while carbon monoxide being slightly lighter is found near the roof. Carbon dioxide must be present in fairly large quantities to cause death, while carbon monoxide is very dangerous to breathe with 0·2 per cent. present. Candles and lamps burn feebly with carbon dioxide present, but the presence of carbon monoxide causes them to burn brighter. Dr. Haldane's experiments show that persons breathing an atmosphere containing 0·1 to 0·2 per cent. of carbon monoxide for a short time become faint and gradually helpless, owing to oxygen starvation of the blood. Its ignition point is 1184° F., and this is lower even than that of firedamp, which is about 1600° F.

It is most probable that carbon monoxide is a far more

[1] See Dr. John Haldane, *Trans. Inst. of Mining Engineers*, vol. viii., p. 549.

frequent cause of explosions, and of loss of life after explosions, than firedamp. The following reasons may be given for this:

(1) Its frequent production in dry and dusty mines when explosives are fired.

(2) Its low ignition point.

(3) The great difficulty of detecting it.

Sulphuretted Hydrogen.—Also called Hydrogen Sulphide. Symbol, H_2S; density, 17; specific gravity, 1·17; burns with a blue flame; is colourless, and has a smell like that of putrid eggs.

Sulphuretted hydrogen is produced in mines owing to the decomposition of substances containing sulphur in brackish or salt water, and is also one of the products of shot-firing. Like carbon monoxide, it is also given off from underground fires, and is chiefly responsible for the term **gob stink** so often applied to the offensive odour, which is a precursor or indicator of spontaneous combustion.

Coal Dust.—Although coal dust cannot be termed a gas, it is, nevertheless, one of the chief causes of the pollution of the air in mines, and is now recognised as a most frequent cause of explosions. It is contended by some that an explosion of coal dust and air is impossible without the presence of firedamp. Like many others, the author believes that the presence of this latter gas is not always necessary, and that a mixture of finely divided dust with air may be ignited owing to an unsuccessful shot or a defective lamp, and cause an explosion of such an extent that it is only limited by the extent of the dust. This ignition of the dust, however, will in most cases have been brought about through the agency of carbon monoxide. For instance, suppose the unwatered roadways of a mine are covered on every available ledge by thick deposits of fine, dry dust. If a blown-out shot, or a severe ordinary shot occurs, two effects may be produced—(*a*) the dust will be dislodged from the roof and sides, raised from the floor, and hang suspended in the vibrating currents of air; and (*b*) this inflammable mixture may be ignited and cause an explosion. The latter effect may be brought about in this way—carbon monoxide with other combustible products from the explosive, accompanied by great heat, is shot out from the face into the atmosphere of coal dust and air; the former is ignited by the carbon monoxide, which is oxidised to carbon dioxide, taking its oxygen from the air and from the moisture in the air;

this sets free the hydrogen in the latter, which, together with the inflammable gases from the heated coal dust and the carbon monoxide still uncombined, are carried along in front of the explosive wave, until a second and a third explosion follow, and so on until the whole area of dust-laden atmosphere is passed. This explains why an explosion of dust generally goes in waves, continuing until it arrives at some distinct break, formed by a wet stratum or watering. It also explains the reason why a coal-dust explosion does not necessarily follow the air current; it is in any case bound to follow the dust, and in some cases it has been known to take a direction exactly opposite to the current.

Prof. Galloway states that one volume of firedamp to 14 volumes of air is explosive, and that one pound of coal dust to 160 cubic feet of air is required to form an explosive mixture; but a very small amount of firedamp—say 1 or 2 per cent.—will be sufficient if coal dust is present in sufficient proportions. Again, the nature of the dust influences the probability of explosion. Some dusts are much more inflammable than others. Samples experimented upon by Mr. Henry Hall were declared by him to be almost as sensitive to explosion as gunpowder itself, notably dust from certain seams in Glamorgan, Monmouth, Durham, Lancashire, Yorkshire and Scotland.

There may be some doubt as to whether a mixture of dust and air is in all circumstances inflammable; but there can be no doubt that if an explosive is used producing much carbon monoxide and generating a great amount of heat, this may so act on the coal dust as to form with it and the air an explosive mixture, even where firedamp is entirely absent.

An explosion of firedamp is brought about in quite a different way from that just described. In the first place, an explosive mixture of firedamp and air not only needs a certain amount of heat to ignite it, but it requires this heat constantly applied for at least 10 seconds before ignition can take place. This does not always occur, the temperature being reduced somewhat in the interval, and thus an explosion is often avoided. If the heat is sustained, hydrogen is liberated from the marsh gas, and immediately ignites and raises the whole to the necessary ignition point. In case of a blown-out shot, then, this mixture will not ignite unless the necessary heat is maintained for this length of time, which seldom occurs.

Where carbon monoxide is present in the gaseous products of combustion, it may ignite immediately the products come in contact with the air; or if a portion of the charge is unconsumed after the coal is blown, and remains fizzing at the back of the hole, the same result may be expected. As has been already stated, it is necessary that complete decomposition of the explosive should take place in the hole, before the pressure is relieved, in order that the proper chemical action may take place; and if this does not happen, owing to the presence of breaks, or soft coal, which cause part of the coal to break down prematurely, grave consequences may follow.

In these several ways a coal-dust explosion may be brought about, with or without firedamp; and although some dusts are more inflammable than others, it is necessary to take all possible precautions, not only to prevent its ignition, but to prevent its accumulation on the sides, roof and floor of the roadways. The following are some of the ways in which explosions of this kind may to a certain extent be prevented:

1. The collier should take all possible precautions in the getting and loading of his coal, to prevent its breaking.

2. Iron tubs with the full number of sides, or good, well-made wooden tubs, should be used.

3. The rails on all faces, drawing roads, inclines and levels, should be well laid and kept in good order.

4. As far as is practicable, roadways should be formed in such a way as to offer little opportunity for the deposition of dust on the roof and sides.

5. Efficient watering arrangements, either in the shape of sprays fixed at stated intervals or attached to the moving tubs, should be used. These should be made to throw fine sprays of water wherever it is possible for dust to accumulate. A watering tank is entirely inadequate, since this will throw the water no higher than the tank, except by the aid of mechanical apparatus.

6. The whole of the requirements of General Rule 12 of the Coal Mines Regulation Act in regard to the firing of shots should be carefully carried out.

7. Accumulations of dust should be regularly removed at convenient times; but before this is done the whole neighbourhood of the accumulation should be well watered. Many accidents have occurred during the removal of dust, owing

to the firing of the dust in the lamps of the men engaged in the work. To prevent this, good lamps should be used and the road well watered.

Modes of Detection of Gases.—**Firedamp** can be detected on the flame of a good miner's lamp when only 2 per cent. is present in the air. The flame of the lamp is first lowered until only a small blue flame is left, when a pale, non-luminous **cap** of flame may be seen, and the percentage of gas present determined approximately by its size. The cap is the small flame made by the gas present in the mine, and visible on the top of the flame of the lamp. Some good firemen's lamps will detect even a smaller amount than that named; while gas detectors, such as **Pieler's, Clowes's, Beard-Mackie's** and **Ashworth's** lamps will detect as little as 0·5 to 0·2 per cent. Of course a great deal depends upon the illuminant, a benzoline flame being much more sensitive than an oil flame. The Marsaut, Meuseler and Wolf lamps ought to detect the gas with 1·6 to 2 per cent. present. Ashworth's lamps with hollow standards have one great merit. As firedamp is lighter than air, a test is of little use unless the light can be brought into the atmosphere near the roof. It is only with such lamps as the Ashworth-Hepplewhite-Gray, that this can be done without risk of extinguishing the light. The apertures at the top of the lamp are first opened, and the ones near the bottom closed by means of the fingers. The lamp is slowly raised into the gas, and, if necessary, air may be admitted through the lower holes by removing the fingers.

Firedamp is dangerous to breathe in certain proportions, although it is not so deadly as carbon monoxide. Persons are often overcome by this gas through trying to remove it, after first leaving their lamps out of danger. Although it may be safe to breathe the atmosphere in which a lamp would burn, it is never wise to enter a place without a light. Prof. Galloway has made some interesting experiments in regard to firedamp and the size of cap shown, and remarks as follows:

The sizes and shapes of the caps corresponding to mixtures of firedamp and air of known compositions are as follows:

1 of firedamp to	15 of air.	Mixture was inflammable.
1 „	16 „	A voluminous, waving, spindle-shaped pale blue cap, 3⅜ in. high.

1	of firedamp to	18	of air.	A similar cap, 2 in. high, which burned rather more steadily.
1	„	20	„	A cap, $1\frac{5}{16}$ in. high, with nearly parallel sides to about two-thirds of its height, and drawn out to a point at the top. This cap was perfectly steady, and more distinct than any of the others.
1	„	25	„	A conical cap, $\frac{1}{2}$ in. to $\frac{3}{8}$ in. high.
1	„	30	„	A conical cap, $\frac{3}{8}$ in. high.
1	„	40	„	A conical cap, $\frac{3}{16}$ in. to $\frac{1}{4}$ in. high.
1	„	50	„	(2 per cent.) An exceedingly faint cap, $\frac{1}{8}$ in. high, the top having the appearance of being broken off.
1	„	60	„	It was hardly possible to distinguish anything above the small oil-flame. If there was any cap, it was represented by the frustum of a cone a little more than $\frac{1}{16}$ in. high.

Carbon Monoxide.—As already stated, carbon monoxide cannot be detected by means of a lamp. Lights burn brighter in its presence, but this is not a sufficient indication.

The best tests for this gas are:

(*a*) The introduction of a small animal, such as a mouse, into places thought to contain the gas. The mouse will show signs of trouble some time before human beings; but there is no doubt that, even where so small an animal is affected, it is time for the work people to be withdrawn.

(*b*) Human arterial blood, diluted and enclosed in a bottle, if uncorked in the workings, will turn to pink if carbon monoxide is present, differing in this way from carbon dioxide poisoning, which turns arterial blood blue. Unfortunately the difference in colour is difficult to detect underground, and it is generally necessary to come to the surface for an accurate observation.

Spontaneous Combustion.—Many mines, notably those of the Midlands, are very subject to outbreaks of fire, due to the spontaneous combustion of the coal. This generally takes place in the goafs, and may quickly spread to the workings. When an underground fire is thoroughly going, it needs more than ordinary care and energy to extinguish it; and, as a rule, it is only possible to prevent its spreading to other parts. Coal, when exposed to the influence of the air, always absorbs oxygen from it, and heat is produced owing to the combination of the oxygen with the carbon of the coal. The rate of increase of heat will be dependent upon two things:

(*a*) The amount of oxygen available, and the rate at which it is absorbed; and

(*b*) The rate at which the heat escapes.

These factors will be affected by the size of the coal, the presence of coal dust, the temperature of the mine, the initial temperature of the coal and the size of the heap. As the coal slowly absorbs the oxygen, combustion takes place and the temperature rises, combustion being more rapid as the temperature increases. If there is no means by which this heat can be carried away the coal will fire. To prevent this it is necessary that a good current of air should be introduced, or the supply of ogygen must be stopped by sealing up the affected parts. No action occurs and no combustion is set up if the coal is prevented from coming in contact with the air, neither will the coal ignite if the air supply is sufficient to carry away the heat generated. It will be seen, therefore, that the method of allowing a small current of air to circulate through the goafs, etc., is a bad one. The size of the coal affects the rate at which it absorbs oxygen from the air, as also does the size of the heap. The greater the surface of exposed coal in relation to its bulk, the greater will be the risk of combustion, provided oxygen is present. Large lumps of coal are less liable to combustion than small ones, and even heaps of fine dust, if more or less compact, will prevent the oxygen from coming in contact with large areas of exposed surface; but if dust or small coal occurs, mixed with larger lumps, or with heaps of dirt, rock, shale, etc., the oxygen is admitted, and combustion will take place slowly, or quickly, according to the conditions already named. Again, the initial temperature will affect the rate of increase of

temperature, for it is clear that, if the coal is heated to begin with, owing to the natural heat of the mine and stratum, or heat inherent in the coal itself, it will stand a greater chance of becoming quickly ignited.

We should therefore recommend

(1) that all small coal and dust be kept as far as possible out of the goafs, and that pillars and other areas of coal be only left where absolutely necessary;

(2) that a good current of air be constantly supplied to the affected parts, so that the heat generated may be carried away as it escapes from the coal; or

(3) that the workings affected be efficiently sealed.

When a fire has broken out it may become necessary, however, either to shut out the air completely from the parts alight, or to take extreme measures, such as the flooding of the mine. In any case it is as well to make arrangements beforehand by which portions of the mine may be quickly isolated or dammed off, so that the fire may be extinguished, or so that it may not spread unnecessarily.

Questions on Chapter XV.

1. Explain the terms transpiration and diffusion of gases.

2. Explain the process by which an accumulation of firedamp may form an explosive mixture with the air of the mine.

3. What are the principal gases which pollute the air of mines? How can their presence be detected, and how can the amount of the more important be determined quantitatively both immediately underground and also in samples brought to the surface? (1901.)

4. Write out what you are able to state as to the proportions of air and firedamp which will produce explosive mixtures.

5. Explain the different ways in which dust is dangerous in mines; what precautions are taken or should be taken to lessen or prevent the dangers caused by dust? (Sketches required.) (1903.)

6. Give the composition and properties of the two following gases: (*a*) Carbon Dioxide, (*b*) Carbon Monoxide.

7. What special regulations should be observed in mines subject to sudden outbursts of gas? (1896.)

8. In a dry and dusty mine liable to give off firedamp, what methods would you adopt for getting the coal, without running the risk of an explosion? (Newcastle, 1902.)

9. It appears from Inspectors' Reports that it is not an uncommon practice for workmen, wishing to enter a place containing firedamp for some trivial purpose, to leave their lamps behind and go forward in the dark. Of what property of firedamp does this show ignorance? (Newcastle, 1902.)

10. What are the causes of spontaneous combustion of the coal in mines, and what steps should be taken to prevent it?

CHAPTER XVI.

SAFETY LAMPS.

THE **Safety Lamp** is a lamp designed to give light in gaseous mines without the danger of igniting the explosive mixtures of firedamp and air present in most mines. The construction of the ordinary safety lamp is based upon the principle that although air can enter freely through the meshes of a **wire-gauze** cylinder surrounding the flame, no flame can pass from the inside to the outside of the gauze, because the metallic wires of the gauze conduct away the heat from the flame so quickly that the temperature of the explosive gases outside cannot rise to the point of ignition. There are many types of safety lamps, but although they differ from each other in many details of construction, the wire gauze is retained in every type, no better means of preventing the communication of flame from the inside to the outside of the lamp having been discovered.

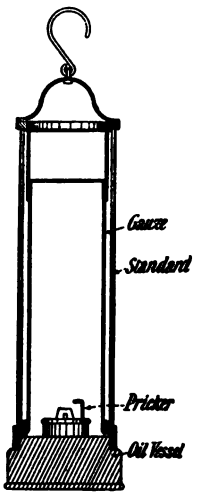


FIG. 174.—The Davy Lamp.

The Davy Lamp.—This lamp (Fig. 174) consists of a small oil vessel surmounted by a cylinder of wire gauze of about $1\frac{1}{2}$ to 2 inches diameter and 6 inches long, a small cap of gauze being placed at the top where the gauze is most liable to be overheated; a brass frame consisting of a screwed rim at the bottom and three upright rods placed

at equal distances apart and connecting the bottom rim to a similar one at top; a metal roof, attached to the frame and provided with a handle for carrying the lamp. When firedamp enters the lamp in small quantities it is ignited by the lamp flame, and may be seen burning as a slight blue cap above the ordinary flame. When the firedamp is present in the lamp in larger percentages it forms an explosive mixture with the air, and a series of slight, rapid explosions may be seen, a long blue flame darting up continually towards the top of the lamp. This flame, however, will not pass through the gauze so long as the wires of the latter continue to carry away some of the heat from the explosive flame. The Davy lamp is not considered to be safe when carried in a strong air current, and General Rule 9 of the Coal Mines Regulation Act prohibits its use in many mines. This rule reads: "Wherever safety lamps are used they shall be so constructed that they may be safely carried against the air current ordinarily prevailing in that part of the mine in which the lamps are for the time being in use, even though such current be inflammable." To improve its safety some Davy lamps are provided with a shield of brass hung on two of the rods or standards, but this is not sufficient protection in most air currents. The Davy lamp does not give a good light, but is capable of detecting small quantities of explosive gas owing to the free access of the air below the flame, and the absence in consequence of smoke. A Davy lamp is unsafe in a current exceeding 6 feet per second.

The Stephenson.—This lamp (Fig. 175) is similar in general construction to that designed by Davy, but has a glass cylinder about five inches high inside the gauze and covered with a perforated copper cap. The air is admitted through perforations in the bottom rim of the lamp frame, feeding the flame, then passing out at the top. By using both gauze and glass the safety of the lamp in a strong current is increased; but its illuminating power is greatly reduced. The Stephenson is unsafe in currents over 10 feet per second.

The Clanny Lamp.—The Clanny lamp also is similar in principle to Davy's; but an improvement both in safety and in illuminating power is obtained by using a cylinder of strong glass round the flame (Fig. 176) and mounting the gauze upon this. Air enters the lamp immediately above the glass cylinder, then passes down to the flame, the products of combustion

finding their way out at the upper portion of the gauze. The Clanny lamp is safe in a current of not more than 8 feet per second.

Modern Improvements in Safety Lamps.—We have now to consider certain very important improvements made in the construction of lamps since the introduction of the Clanny,

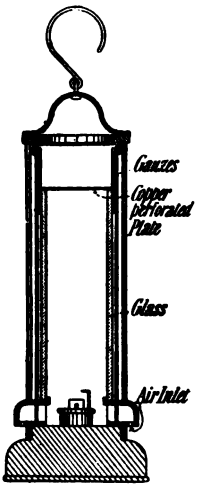


FIG. 175.—The Stephenson Lamp.

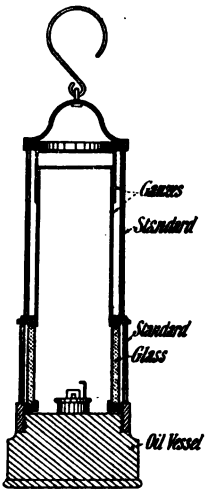


FIG. 176.—The Clanny Lamp.

but it may first be noted that even the most modern lamps contain in some form the three main features of the lamps just described, viz.:

1. The gauze, first used by Davy.
2. The glass, first used by Stephenson.
3. The gauze mounted above the glass, first used in the Clanny lamp.

When firedamp burns, carbon dioxide and water are produced; consequently, if a lamp is allowed to burn for any length of time in an atmosphere containing a quantity of firedamp, the probability is either the carbon dioxide gas produced will gradually fall back upon the flame and extinguish it, or the gauze will become so much heated as to allow the

flame to pass through to the outside inflammable atmosphere. It is necessary, therefore, that in the construction of any form of safety lamp these two points should be taken into consideration. It should also be remembered that as the speed of the air current in many mines exceeds the speed at which the Davy, Stephenson or Clanny lamps may be considered safe, the requirements of General Rule 9 have not been met in these lamps. It is consequently necessary to consider how these principles or requirements have been applied or met in the best modern lamps.

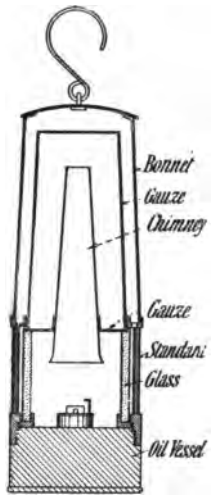


FIG. 177.—The Mueseler Lamp.

The great aim has been to produce a lamp which will either go out instantly in the presence of an explosive mixture, or will resist any explosive current the lamp will have to meet in the mine in which it is used. The first principle was fully secured in the **Belgian Mueseler** lamp. The second principle was secured more or less effectively in lamps like the **Marsaut**, the **Mueseler, Bonneted Clanny**, etc., *i.e.* lamps provided with a shield or bonnet.

The Mueseler Lamp.—This lamp (Fig. 177) is similar to the Clanny in all respects except that it is provided with a chimney fixed in the centre of the lamp, starting from a little distance above the flame and extending to near the top of the lamp. The chimney is bell-mouthed just above the flame, and narrows to the top. The action of this chimney is as follows: When the lamp is surrounded by pure air, *i.e.* when the flame is fed by pure air, the quantity of carbon dioxide produced is so small that it is carried up the chimney by the ascending current as rapidly as it is formed, but when the lamp burns in an atmosphere of firedamp and air, at an explosive point, the carbon dioxide produced is much greater in quantity and cannot pass upward with sufficient rapidity. The consequence is that the gas quickly accumulates in the

chimney, filling it up and at once becoming an extinguisher. This was the first and most effectual attempt to render a lamp safe in an explosive atmosphere.

The air to feed the flame passes first through the outer gauze, then through a small horizontal gauze placed between the metal chimney and the glass, and down the outside of the chimney to the flame. The products of combustion in ordinary circumstances pass up the metal chimney, through the gauze cylinder and so into the atmosphere. The metal chimney therefore serves two purposes: it not only acts as an extinguisher, but causes the air to be deflected on to the flame, keeping the glass cool and supplying a quick current to the flame.

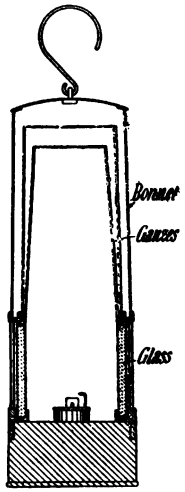


FIG. 178.—The Marsaut Lamp.

The Marsaut.—The **Marsaut** lamp (Fig. 178) is also very similar to the Clanny, but is supplied with several gauzes one within the other, the effect of which is to increase its security against an explosion of gas within the lamp. This effect can easily be understood, as it is quite clear that using more than one gauze has the effect of reducing the space available for explosive gas within the lamp, while at the same time it greatly increases the gauze area. The Marsaut lamp has the further advantage of not being easily extinguished in the presence of gas in explosive quantities, while at the same time it is almost certain to become extinguished if the quantity of flame within the lamp becomes serious. As a rule, the Marsaut is used with a bonnet, and sometimes with less than three gauzes. It is also used very often with a **Deflector**, and in fact almost all lamps besides the ones already named are constructed like the Marsaut, each having their respective improvements added. The gauze used in the cap of the lamp has usually 934 apertures to the square inch. The Marsaut is not considered the best lamp for gas-testing purposes, but as it gives a good light all round, does not

easily go out if roughly handled and does not quickly get hot, it is the favourite lamp amongst coal miners in this country. The Marsaut is considered safe in currents up to 100 feet per second.

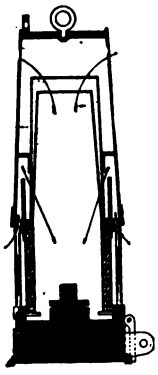


Fig. 179.—The Deflector Lamp.

The Deflector patent (Fig. 179) may be applied to various forms of lamps. It consists of an arrangement for guiding the air into the lamp, and this is done in such a way that the air is prevented from impinging on the gauze. A vertical cylinder of brass 1¼ ins. high, placed just inside the bonnet, acts as a guide, directing the air current upwards until it is stopped by an angle-ring attached to the shield on the one side and touching the outer gauze on the other. It also has a flange on this side projecting downwards, which terminates immediately above the top of the cylinder of brass already described. The inlet air may therefore enter through the holes in the usual horizontal flange, pass upwards to the top of the brass cylinder, and here be turned or deflected downwards on to the flame, arriving there as a steady current and warmed by its passage through the channel formed by the warm brass cylinder and gauzes.

Ashworth-Hepplewhite-Gray.—The chief characteristics of this lamp (Fig. 180) are the use of a conical glass instead of a cylindrical one, and the employment of hollow standards by means of which air can be admitted to the light chamber from the neighbourhood of the top of the lamp. By this means it is possible to get more accurate tests for gas than is the case with those lamps which admit the air just above the top of the glass, as it invariably happens that accumula-

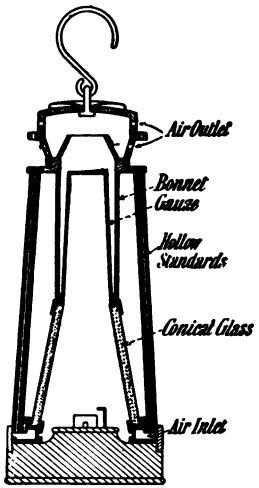


Fig. 180.—The Ashworth-Hepplewhite-Gray Lamp.

tions of firedamp and air are found near the roof. On the whole, this lamp is more generally used for gas-testing purposes than as a collier's lamp. In general construction it is similar to the lamps described, but the gauze is necessarily of finer mesh, and provision has to be made for the admission of air below the light. It is made in various forms, according to the purpose for which it is required; in one form a short bonnet is combined with the hollow standards and arranged to admit the air through holes in its sides; these may be shut if necessary, and the air admitted through openings at the bottom of the standards. By the use of a conical glass it is possible to get a good light to the roof, and for practical work this is a most important feature.

The Wolf Lamp.—Although not largely used in England, this lamp is by far the most commonly employed on the Continent, and large numbers are also in use in America. It is very similar to the Clanny in general construction, and is used either with or without a bonnet. Its chief characteristic is the light it gives. This is not only so placed in the light chamber that it gives far greater illuminating power than any other form of lamp, but it has a self-lighting device by means of which the lamp can be relit at any time if the light is extinguished. This self-lighting device consists of a roll of percussive caps placed near the wick, which can be fired by the operator turning a small lever at the bottom of the lamp. The great benefit of being able immediately to relight the lamp in case it is extinguished must be apparent to every workman, especially as lamps are regularly put out by being upset, etc. Of course, there is a certain element of danger in relighting a lamp in an explosive atmosphere, but with reasonable care it may be safely accomplished if the lamp is a good one, thus enabling the miner to reach a less dangerous atmosphere. Another important feature in the Wolf lamp is the locking device. This consists of a small catch attached to the inner side of the lamp bottom in such a way that it cannot be handled from the outside. When the bottom is screwed up, the catch fits into a slot, and can only be withdrawn therefrom by means of a powerful magnet. It will thus be seen that there is no danger of withdrawing the lamp bottom while in the mine. This is a very necessary precaution for most lamps, but especially for a lamp possessing a self-lighting device like the Wolf.

Lamps for Detecting Gas.—At most collieries it is rarely found that special gas-detecting lamps are in regular use other than those used by the whole of the workmen ; and as a rule it is better that all the men should be supplied with good lamps, capable of detecting, say, 2½% of explosive gas, rather than that they should be supplied with less safe lamps and a few delicate indicators provided for those engaged in inspecting for gas. No doubt the best method is to use a lamp for general purposes like the Marsaut, Ashworth, Wolf or Stokes lamps, which is capable of being fitted with a special arrangement for the

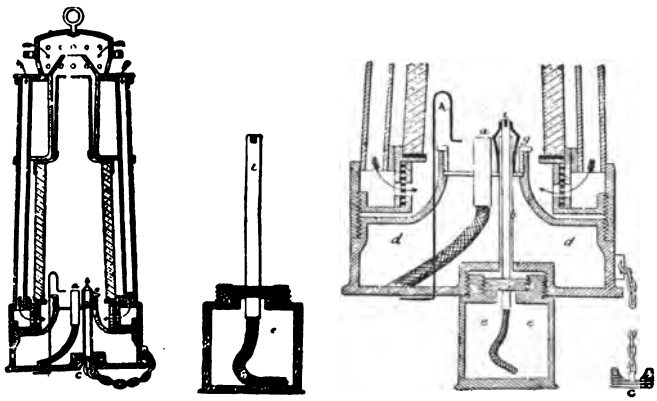


FIG. 181.—Stokes Gas-Detecting Lamp.

detection of low percentages of gas. There are many adaptations of this kind, and on the whole they are much better than mere gas detectors.

Stokes Lamp.—In this case a special vessel containing alcohol (Fig. 181) and provided with a long wick tube is arranged to screw into the bottom of the oil vessel of an ordinary Hepplewhite-Gray lamp. By an ingenious arrangement of the wick tubes, a flame of alcohol readily takes the place of the ordinary flame, and by this means a more accurate test for gas can be made. After the test, the ordinary wick can be relighted and the alcohol flame extinguished, the special vessel being then withdrawn or left in position in case further tests are desired. In the illustration (Fig. 181) *a* is the ordinary wick ; *b*, a

tube through the oil vessel ; *c*, a plug ; *d*, the ordinary oil vessel ; *e*, the alcohol vessel ; *g*, the sprig cap ; *h*, the wick ; *i*, the tube with wick from the alcohol vessel.

Ashworth Lamp.—This lamp is similar to the form already described (p. 296), except that it is provided with ground or blackened glass behind the flame ; and that benzolene is used as the illuminant. By using benzolene a hot flame is produced ; and when this is reduced to a suitable size, the cap, in case firedamp is present, can easily be seen against the improved background. In this way it is possible to have an indication of gas if only 0·5 per cent. is present ; and, as the lamp is safe and gives an excellent light at the same time, it is a most useful lamp for the purpose.

Beard-Mackie Indicator.—In this indicator a small device is used which may be fitted to almost any lamp. It consists of a short ladder, the rungs of which are formed of short platinum wires, and is placed immediately above the flame of the lamp. The bottom rung is of iron wire, and is intended to indicate the best height at which the ordinary flame should be during the test. The platinum wires above this are arranged so as to show varying percentages of gas. The principle of the tester is based on the fact that the wires of platinum are exceedingly sensitive to heat, so that even though a firedamp cap is invisible, one or more of the wires will glow if a flame of firedamp is burning. The proportion of gas present is calculated according to the height of the last wire affected by the firedamp flame. This provides an exceedingly delicate test, less than one per cent. of firedamp being capable of detection, and as the ladder is easily fitted, inexpensive, and causes no alteration in the construction of the lamp, it is a good arrangement for the purpose.

There are some other gas detectors, as **Peiler's, Chesnau's, Liveing's Indicator** and the **Shaw Gas Tester,** arranged to indicate the presence of very small quantities of firedamp, but they are not in general use, and need not be described here.

The Light.—In attempting to improve the safety of the lamp, the light must not be lost sight of, as it is quite clear that a good light must be provided if the collier is to do his work in comfort and at the same time in safety, by being able to detect the presence of gas or to discover breaks or slips in the roof and sides of his working place. A lamp

which gives a good light is quite as safe in an explosive atmosphere and as quick to indicate the presence of gas as a lamp giving a poor light.

Under good conditions the best lamps give a light equal to about 0·75 candle power, but this is in case the lamp is in good condition and well supplied with fresh air. In most mines there may be a slight deficiency of air and quantities of coal dust hanging in suspension in it. The lamp will then become dirty and the gauze clogged with oil and coal dust. When the lamp has been burning for some hours, especially if it has been allowed to smoke, soot becomes deposited near the outlet, and this, together with smoke from explosives and the carbon dioxide in the air, reduce the power of the light considerably.

In addition to these external influences, there are other equally important features in regard to the lamp itself which affect the quality of the light. When air enters above the flame there is a probability that some of it may pass upwards and out of the lamp with the products of combustion unless it is deflected, or some other provision made whereby it must first pass to the flame, but as a rule these lamps have the disadvantage of becoming too easily extinguished in the presence of gas. By admitting the air below the flame, as in the Stephenson and Ashworth-Hepplewhite-Gray types of lamps, the current is obliged to pass first to the flame and then upwards to the top of the lamp in a perfectly natural manner, and this not only enables a good light to be got, but prevents the accumulation in the light chamber of explosive mixtures or of volatile gases from the illuminant. The ventilation of the lamp is clearly an important matter, and if this is to be satisfactorily accomplished, in addition to the points named, there must be a proper relation between the area for the admittance of air and the area of the outlet. The thickness of the glass cylinder also affects the light. It may be said that two-thirds of the light is lost either by reflection or absorption in the thick glass ordinarily used in lamps. A thinner glass, however, would be quite unsafe, and probably the only alternative is to use a conical glass cylinder like that of the Ashworth lamp, so that the available light may be used to the utmost benefit.

Illuminants and Forms of Wick.—A mixture of one-third

petroleum and two-thirds rape or seal oil was recommended by the Accidents in Mines Commission, but the proportion of mineral oil in the present mixtures is much higher than this. This mixture does not produce a very hot flame, although a good light is obtained. As the mixture is very volatile, great care has to be taken in filling the lamp and in handling it when in the mine. Flat wicks as a rule are the best; in this case the proportion of flame which is in touch with the air is greater than in a circular wick. Two separate wicks placed near enough to each other to admit of one flame burning the unconsumed carbon particles of the other are used with good results.

Electric Lamps.—For lighting the workshops, sidings, screens, engine house and the pit bank, no better light than the electric light can be used. It can also be conveniently and safely used in sinking pits and, in some mines, in the neighbourhood of the pit bottom and along the main intake air-ways. In the workings it is unsafe in its ordinary form; and, in fact, the system would be inconvenient, as there would be some difficulty in extending the installation as the workings and roadways advanced. A few portable electric lamps have been tried, such as the Sussman, but are not largely used.

FIG. 182.—The Sussman Lamp.

The **Sussman Lamp** (Fig. 182) consists of a small storage battery charged with electricity for 10 or 12 hours' use, having a small incandescent burner above it of about 4 or 6 candle power. It thus gives an excellent light, but has a few disadvantages. It is much heavier than an ordinary lamp, and is costly both to buy and maintain. It must be remembered that as the light of such lamps is independent of the outside atmosphere, they give no indication of the presence of gas, and continue to burn in atmospheres which are dangerous either because of their inflammability or their suffocating character.

Questions on Chapter XVI.

1. Why does a safety lamp prevent communication of flame from the inside to the outside of the gauze when placed in an explosive atmosphere?

2. Describe an ordinary Clanny lamp, and show where the fresh air enters it and where the products of combustion leave it. (1900.)

3. Show by means of a drawing the construction of the following safety lamps:

(*a*) Marsaut.

(*b*) Mueseler (unbonneted).

Describe the circulation of air in each, and show what prevents the communication of flame from the interior to the exterior of each when it is placed in an explosive mixture of firedamp and air.

4. What are the main principles affecting the construction of the most modern safety lamps?

5. Describe two types of safety lamps with which you are acquainted.

6. Describe a good gas-detecting lamp.

7. How can the safety lamp be used as a firedamp detector? Describe some lamps arranged for this use. (1898.)

8. What should a miner do who is in possession of a lamp which has gone out or has been rendered unsafe through accident?

9. Describe two gas-detecting appliances, and say why electric lamps are unsuitable for use in fiery mines.

10. What points must be taken into consideration in the construction of a lamp in order to provide as good a light as possible?

CHAPTER XVII.

PREPARATION OF COAL FOR THE MARKET.

THERE are few mines from which coal of so good a quality is produced that it is unnecessary to treat it in some way before it is sent to the consumer. As it comes from the mine, coal generally contains a greater or smaller quantity of foreign substances, such as shale, fireclay and pyrites; or, it may be, an inferior seam of coal has been filled into the tubs with a good seam, and these must be separated from each other afterwards. It is important to have good clean coal for all industrial purposes, and consequently great attention must be paid to the various methods adapted for cleaning it. As a rule, it is also necessary to divide the coal into various sizes, as it is of greatest commercial value when classified, sized and cleaned most perfectly. So it is found that at the best modern collieries elaborate arrangements are made for handling the coal at the surface and putting it through such processes of screening, cleaning and coking as will secure its utmost utilisation. These processes include:

1. Screening and Picking.
2. Conveying, Elevating and Lowering.
3. Washing.
4. Coking and Recovery of Bye-products.
5. Manufacture of Briquettes.
6. Loading into Trucks, Barges, Ships.

Coal Tipplers.—The lowering of coal from the bank to the screens is done by means of **tipplers** and **shoots**, or **lowering belts**. These should be constructed so as to cause little damage to the coal, as, it is needless to say, that large unshattered coal is more valuable than small or broken coal.

Open Tipplers.—The chief drawback to the open tippler is that there is a distinct fall from the tub to the screen. In Fig. 183 *B* the delivery is in the direction of the bars, but the coal falls in

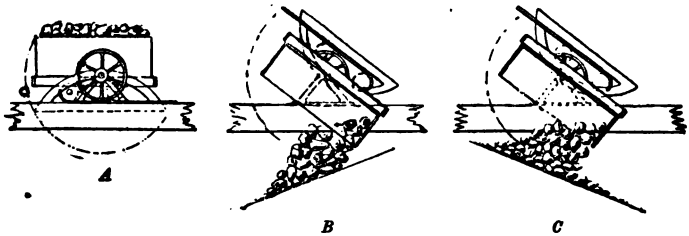


FIG. 183.—Open Tipplers.

a mass, and the upper part of the screen bars, instead of serving as a screen, is only able to guide the coal in mass to the lower portions. Where the tippler is turned in the opposite direction (Fig. 183 *A* and Fig. 183 *C*), the same effect is produced. To avoid this disadvantage, some tipplers have a movable door above the tub, which is opened slowly by a lever when the tub has been overturned. This prevents the too early delivery of the coal, but it cannot be said to be a great improvement on the former method.

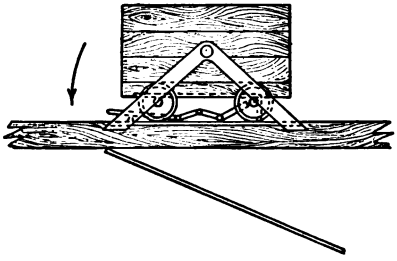


FIG. 184.—Open Tippler.

Heenan's Patent Gravity Tippler.—This is a **through tippler**, *i.e.* a tippler which allows the tub to enter at one end and to pass out at the other. It is a good example of the gravity class, the weight of the coal being sufficient to operate it. It is capable of dealing with large quantities of coal rapidly and carefully. The tippler consists of two mild steel rings, built up of channel steel and jointed to the centre boss by arms of channel steel of the same section, and strongly held together by plates, as seen in Fig. 185. The end rings are joined together

by side plates ½ in. thick, and also by angle irons, forming the rails for the tubs. The whole is suspended on a strong shaft 4 in. diameter, which is mounted on two bearings. It will be seen from Fig. 185 that the tippler holds three separate tubs which rotate in a sort of squirrel cage, the rotation being achieved by the weight of the loaded tub *A*. The action then is as follows: A loaded tub from the weighing machine is run into the tippler with considerable velocity, when the impact will eject the empty tub already standing on the horizontal track. When at rest, the tippler is held in position by two

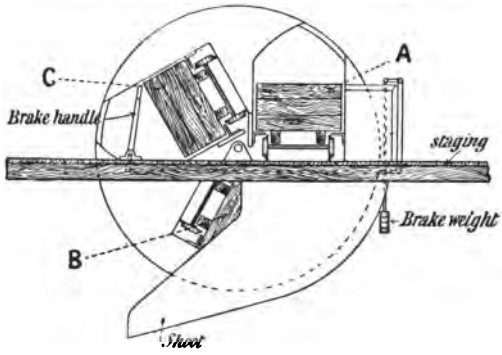


FIG. 185.—Heenan's Gravity Tippler.

powerful brakes which pass round the periphery of the two end rings. These brakes are actuated by a lever arrangement (Fig. 185) under the control of the attendant; on moving the lever the brakes are lifted, and the tippler rotates one-third of a revolution; it is again brought to rest at the next horizontal position, and the operation is repeated. Meanwhile the tub *A* now takes up the position shown at *B*, and the tub side, as well as the side plate of the tippler, makes an angle of 30°, which, with the tippler shoot, also inclined at 30° in the opposite direction, make a temporary hopper into which the coal is discharged. The coal is thus locked in this hopper until the next tub is run in, when the tub takes up the position *C*. This arrangement is of great importance, as the stop at the point *B* gives the tub time to empty itself gently of its contents, instead of allowing the coal to fall from the position *C*, as is the case with

the tipplers already mentioned. The tippler is sometimes fitted with an automatic stop, but with a good attendant this is unnecessary. It may also be fitted, if necessary, with an ingenious arrangement of automatic claws which grip the buffers of the tubs, and thus holds them in position. These tipplers are also made to hold 4 tubs. The advantages claimed for this tippler are briefly as follows :

(*a*) It is actuated by gravity alone, thus effecting a saving in engine power and in cost, and in the maintenance of troublesome gearing ;

(*b*) it possesses an advantage over other three-way tipplers by reason of the fact that the rail level for the tubs is considerably below the centre line of the tippler rings ;

(*c*) it is easy to manipulate, and can be attached to any existing plant ;

(*d*) it will tip up to ten tubs per minute ;

(*e*) it requires little lubrication and attention.

The "Heenan" tippler is made by Messrs. Heenan & Froud, of Birmingham.

The "Rigg" Patent Power-Driven Coal Tippler.—The pit tub on this system oscillates only ; that is to say, it simply moves backwards and forwards. The movement is rapid, except for a short distance just as the coal is about to leave the tub, when the action is slow, thus enabling the coal to pass on to the belt, or intermediate jigging screen, slowly and carefully. The diagram (Fig. 186) shows the manner in which the varying "forward" and "return" movements are obtained. The shaft *G* is driven at a uniform speed, and the pin on the crank H^1 upon this shaft is connected

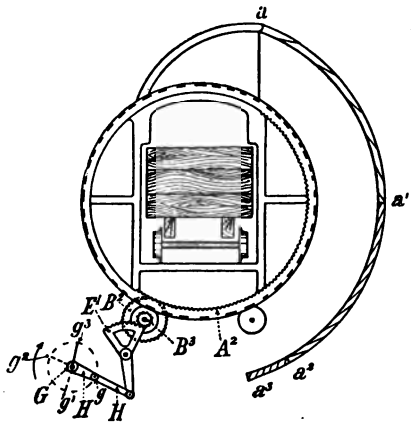


Fig. 186.—The "Rigg" Tippler.

to the arm H, and so through the toothed segment E^1 communicates motion to the pinion B^3 and wheel B^2, which are geared into the rack A^2 attached to the tippler. One revolution of the shaft G causes the double oscillation of the tippler through the arc indicated by the dotted lines. It is important to observe that the three equal arcs gg^1, g^1g^2 and g^2g^3 of this portion of the path of the uniformly travelling crank-pin correspond, as stated, with the varying velocity of travel of the tippler, as indicated by the letters aa^1, a^1a^2, a^2a^3, and this variation, as well as that of the return of the empty tub, is that which is best adapted to secure an extremely rapid motion when coal is not leaving the tub, and a slow one just prior to and during the delivery of the coal on to the screen bars.

Screening and Picking.—In most cases **Large Coal** sells at the highest price, but in other cases, notably the anthracite coal trade, **Nuts** of different grades command a higher price than the large, and it pays the colliery owner under favourable conditions to break the large coal, and to convert broken coal into different grades of **Cobbles**, **Nuts**, **Peas**, and **Slack** or **Duff**.

Large Coal is the term applied to all coal above a diameter of about 5 inches.

Cobbles consist of pieces of coal of $2\frac{1}{2}$ inches to 5 inches diameter.

Nuts are the small pieces of coal which will pass through screen bars from $1\frac{1}{2}$ to $2\frac{1}{2}$ inches apart.

Pea Nuts or **Peas** are the smallest sizes of nuts, say $\frac{3}{4}$ to $1\frac{1}{2}$ ins. cube.

Slack is the fine coal or dust which is formed during the holing or undercutting of the coal and through the breaking up of the larger pieces. As a rule the term includes all coal or dust which will pass through the smallest sized belt or screen bar used at a colliery. In some parts the terms **Duff** or **Smudge** is applied to this small coal dust.

Dirt.—Foreign matter in the coal of whatever kind is called dirt by the miner, and may include shale, sandstone, fireclay, bands of soft metal or ironstone.

In order to see how these different grades and qualities of coal are obtained, we must follow the process gradually from the time it is tipped from the tippler to the moment it is being discharged into coal waggons or barges.

Fixed Bar Screen.—In some few cases it is unnecessary to pick the coal, and then it may be tipped through a fixed bar screen,

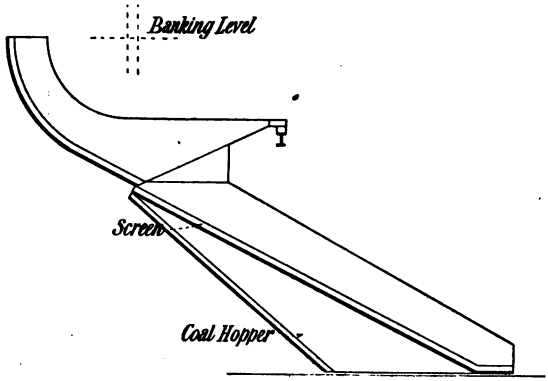


FIG. 187.—Fixed Bar Screen.

which simply separates the various sizes, and from which it may be discharged directly into carts or waggons. Such an arrangement is shown in Fig. 187. The screen is constructed

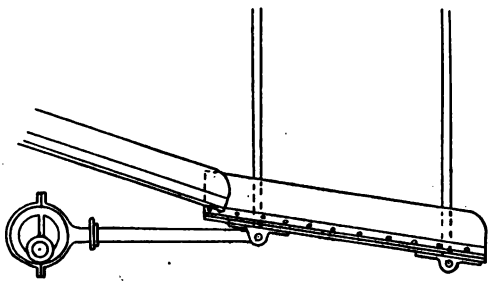


FIG. 188.—Jigging Shoot.

of mild steel plates and tapered screen bars, fixed at such an angle that the coal gently descends direct into trucks, or if necessary, to a picking belt. The screen bars are of steel, tapering so that the coal cannot become wedged between them, and the pitch arranged to suit the various sizes of coal required.

A **Hopper**, or funnel-shaped compartment, is provided below the screen as shown.

A **Jigging Shoot** consists of a box-like arrangement (Fig. 188) constructed of steel plates and angles, and suspended by means of hanging rods in front of the screen to receive the coals from it, and to distribute them gradually and evenly over the belt. The shoots are oscillated by means of eccentrics, keyed to an eccentric shaft.

Jigging Screen.—Two kinds of jigging screens are adopted—the **fixed** and **shaking** frames. In Fig. 189 is shown a jigging

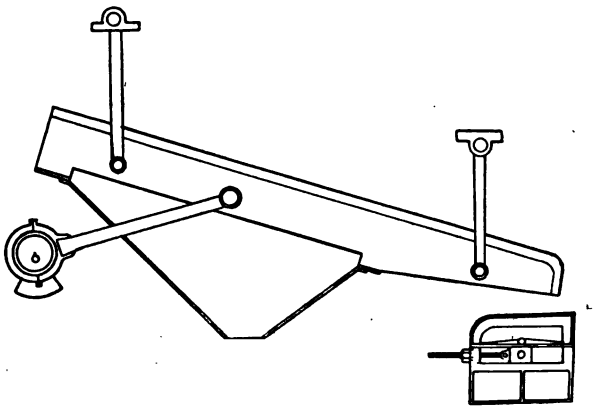


Fig. 189.—Jigging Screen.

screen with shaking frame. It consists of an outer framing, from which is supported the jigging screen proper, which is provided with perforated plates or wire grids, and oscillated so as to separate the various kinds of coal. The illustration shows the shaking frame, the hopper underneath the screen, the rods for suspending the frame, the eccentric for driving the frame, and the end of the picking belt.

Duplex Shaking Table.—Shaking tables are used for the purpose of more thoroughly screening the coal than can be done by ordinary screen bars. A very efficient table is that of Messrs. Meguin & Co., of Dillingen, Saar, and is used at a large number of collieries in Germany. It consists of two sieve-boxes, and the principal advantages of the apparatus

consist in the balancing of these two boxes, in consequence of which the apparatus works without any shock either on the foundation or on the framing, so that it may be used without there being any danger of vibration or damage to the building in which it is placed. The shaking table is provided with straight inclined sieves resting on four vertical pillars, mounted in ball bearings, the upper sieve being supported and the lower one suspended. Horizontal circular motion is imparted to the table by means of two vertical crank shafts driven by bevel wheels. Through the rotary motion and the inclined position of the sieves, the coal is given a slightly oscillatory and descending motion, whereby the various sized pieces, and especially the dust, are separated. Thus the coal is exposed to little shock, and the product obtained is very free from dust. The small coal leaves the shaker below, and the sized pieces at the end or sides as required. The output of such a table is about 160 tons per hour.

Screening and Picking Belts and Conveyors.—After passing over the screens, the coals pass, according to their size,

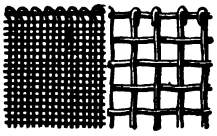


FIG. 190.—Wire Gauze for Screening Belt.

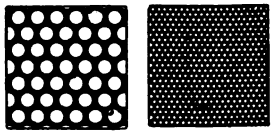


FIG. 191.—Perforated Plates for Screening Belts.

to various travelling belts, by the side of which are attendants whose duty it is to pick out all dirt or inferior qualities of coal associated with the coal. The belts are moved by steam or electric power in the form of small engines or motors, which drive a drum round which the belt passes at one end, a roller being provided at the other.

Belts may be divided into three classes:

1. Wire Gauze Belts.
2. Perforated Iron, Steel or Copper Plates.
3. Plates or Conveyors.

Wire Gauze Belts, similar to Fig. 190, are very generally used in some districts. These are specially woven in any mesh that

may be required for the various sizes of coal, and without doubt are most useful and convenient, and are not so heavy to drive.

Perforated Plates (Fig. 191), made of iron, steel or copper, are used. Holes varying in size from $\frac{1}{8}$ in. to 4 in., and either round or square in shape, are adopted, the plates being of varying thickness up to $\frac{1}{4}$ in.

Conveyors or Plates, similar to those shown in Fig. 192, are now being largely used.

The mode of driving the various belts is similar in most cases. In Fig. 192 is shown a good coal belt made by Messrs. Head, Wrightson & Co., Ltd. It may be described as follows: *a* is the driving end frame; *b* is the trailing end frame, and is arranged so that the belt can be tightened when required; *ccc* are the intermediate standards, provided with stay bolts, thus making the belt firm and rigid; *d* is the belt framing, consisting of steel angles, the top ones being 4 in. by 3 in. and the bottom 3 in. by 3 in.; *ee* are the tumblers, made hexagonal in shape and fixed to the tumbler shafts; *f* shows the belt chains, formed of steel links riveted together, with centres of 12 inches—these chains travel over rollers *gg*, and these run in cast-iron bearings as shown. The chains also carry the tray plates *h*, which are shaped as shown in detail, to give additional strength and to prevent leakage of coal; they are secured to the chain by rivets.

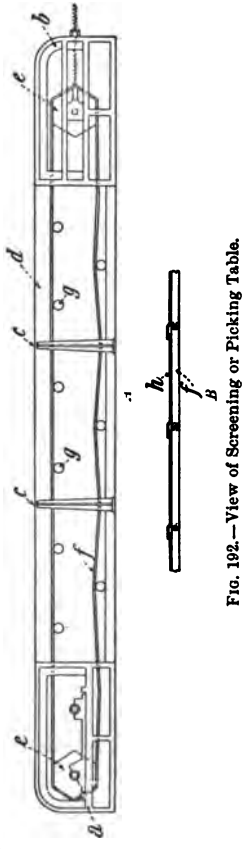


FIG. 192.—View of Screening or Picking Table.

In some cases a deflecting belt is added to the trailing end. This is so arranged that a portion of the belt and framing can be raised or lowered so that coals can be loaded into the trucks without breakage (Fig. 195).

Patent Picking Table.—A method of picking now being largely adopted is that shown in Fig. 193. This consists of an annular steel plate or table, which revolves horizontally on rollers and on to which the coals from the screen are evenly distributed. They are then picked and cleaned on the same, as the pickers stand round the outer and inner circumferences of

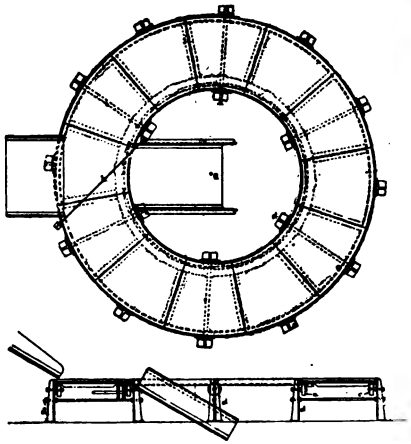


FIG. 193.—Patent Picking Table.

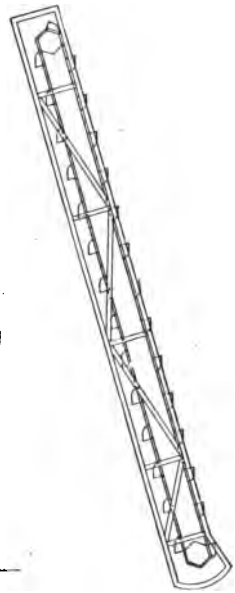


FIG. 194.—Elevator.

table. A scraper is arranged to remove the coals from the table, sliding vertically in guides, and balanced by means of weights. By this scraper the coal is directed into the shoot, and thence into the waggons. Standards support the angle rings of the table and receive the spindles of the rollers.

Elevators.—Elevators for lifting large quantities of coal from the screens, shoots or other places into washeries, ovens, etc., are often required. A good example of one of these is shown

(Fig. 194). It is constructed of steel angles, framed together as shown, provided at the lower end with a boot. This has sliding blocks arranged to be moved up or down to keep the chains tight. At the upper end of the framing, strong steel angles carry the tumbler carriages. Buckets made of steel plates $\frac{3}{16}$ in. thick, jointed at the corners with steel angles, are secured to the chains by $\frac{5}{8}$ in. eye-bolts. The back plates of these buckets are specially stiffened to give strength, and

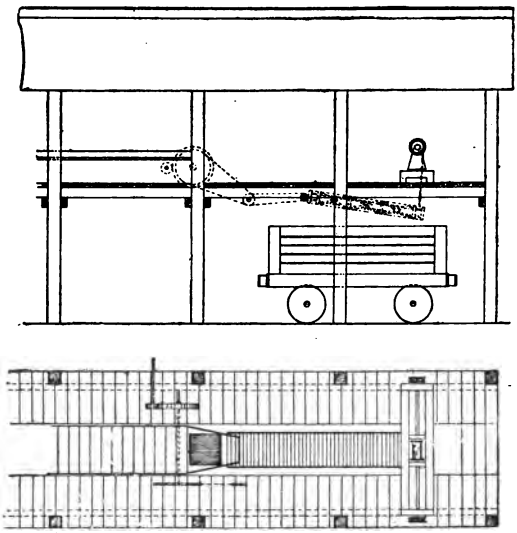


FIG. 195.—Heenan & Froude Lowering Jib.

each bucket has a convex strengthening strip round the cutting edge. In this way large quantities of coal or slack can be constantly raised almost any height, and at speeds up to 70 feet per minute.

Lowering Jib.—Fig. 195 shows an arrangement for lowering the coal into the waggons and for conveying the slack away by means of a spiral conveyor, made by Messrs. Heenan & Froude, Birmingham. The travelling shoot or lowering jib consists of a self-contained lattice girder frame, hinged at the top and left free at the bottom, and it can be operated by either hand

power or a power-driven arrangement working the worm hoisting gear, which enables the jib to be fixed easily at any height desired. The belt plates are of a peculiar corrugated section, giving strength and lightness, and the corrugations also prevent the coal from running down the shoot when placed at a steep angle. These plates are made in various sizes to suit other portions of the belt and the existing positions. By this arrangement, tender coal can be lowered into the waggons without breakage, and the better topping up of the waggons is facilitated, as it not only conveys coal right to the bottom of the waggon, but will at the same time load well up over the top of the highest waggons in use.

Methods of Coal Washing.—The principle involved in nearly all coal washers is the same, and their action is based on the fact that in nearly all cases the impurities combined with the small coal, as it leaves the pit, are of greater specific gravity than the pure coal. This circumstance has enabled mechanical means to be employed which would not otherwise be possible. It has been found that if materials of different specific gravities, and approximately of the same size, are placed in a sieve and jigged up and down in water for a sufficient time, they will arrange themselves in layers according to their density, the heaviest at the bottom and so on. Machines have also been constructed on similar lines with a fixed sieve (Fig. 196), on which the coal to be treated is deposited, and a large piston or pump fixed in a convenient position to give an intermittent and upward motion to the water; in this case the water is given the motion instead of the sieve, with similar effect. Machines on this plan have been in use for some time with very satisfactory results, and for washing nut coal (p. 307) the method is especially good. It is found, however, that the great difference in the sizes of small coal makes it impossible to obtain the best results when all of it is treated together in the same machine and under the same conditions. Thus, the attention of inventors was some time ago directed to solve this difficulty, and machines based on the principle of "classify and then wash" were introduced.

It was found that, with coals screened into nearly the same sizes, each size being treated separately and the conditions being slightly altered, viz., the number and length of the pulsations

of the water, a much more perfect separation was effected. And furthermore, the discovery was made that if a layer of some other material, such as felspar, of a greater specific gravity than the coal and a lower specific gravity than the shale or other impurities, was placed on the grating or perforated plate on which the coal was washed, it would act as a kind of filter through which the shale would pass and on the top of which the coal would remain.

Recently, a washer has found considerable favour in this country based on the opposite principle to that named above, viz., "wash first then classify." In this case the whole of the coal is washed together, and afterwards the various sizes are

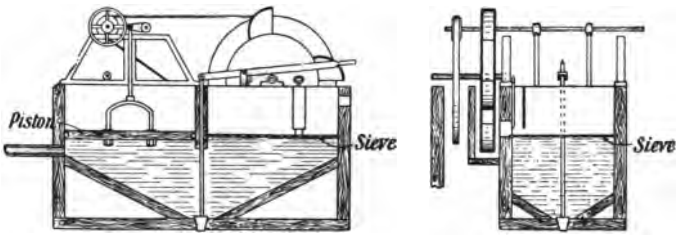


FIG. 196.—Coal Washing Machine with Fixed Sieve.

separated from each other and filled into the waggons. By this means it is claimed that fewer washers are needed; the coal can be more exactly sized; there is no loss of coal as slurry, *i.e.* half-washed coal, and the fine coal is more thoroughly dried before entering the waggon.

In most washers great difficulty is experienced in the recovery of what may be termed the float coal, *i.e.* the finest coal floating on the surface of water, in a condition suitable for coking or firing, and, what is included in the recovery of the fine coal, the clarifying or clearing of the water, whether it be run to waste or used again in the washery. It is recognised that whichever of the two systems named is adopted, it is advantageous to get rid of the dust before washing.

Trough Washers.—Several systems are at present in use, which may be said to be merely improvements on the old **Trough Washer.** Here again the process depends for its success on the varying specific gravities of coal and dirt. Water

carrying the unwashed coal flows through a large trough and is met by trays or screws working in an opposite and upward direction, with the result that the heavier dirt settles in the trays, is carried upwards, and ultimately deposited in the dirt waggon.

Washing Tables, similar in most respects to those used for gold washing, are also used in certain countries; these may be said to be based both on the principle of gravity and momentum, the material being jigged up and down while gradually settling.

We have then two main systems of washing, viz.:

(*a*) Coal sized before washing.
(*b*) Coal sized after washing.

While the various machines may be included in the following:

(1) Jigger Washers.
(2) Trough Washers.
(3) Washing Tables.

Description of a Jigger Washer.—The most important coal-washing plants on the jigging principle at present at work are the **Coppee,** the **Luhrig,** the **Sheppard,** the **Humboldt** and the **Baum.** It will be sufficient if one of these is described in detail.

The Sheppard Coal Washer (Fig. 197) represents a plant capable of sizing and washing 350 tons of coal per day of 9 hours. This plant is intended for the preparation for the market of nuts, peas and duff coal. The hopper *A* receives the coal from the trucks, which is then raised by the elevator *B* to the sizing screen *C*. The duff is treated in the felspar machines *D*, the peas in the machine *E*, and the nuts in the machine *F*. The settling chamber *G* receives all the water from the machines. The elevator *H* raises the coal to the bunker *I*. The engines are shown at *J*.

Fig. 197, showing a plan and an elevation, illustrates a plant designed to wash 500 tons per day of 10 hours, and it was recently erected for Messrs. Crawshay Bros., Cyfarthfa. This plant differs from the previous plant, inasmuch as the coal in this case is used entirely for coke making. The coal is sized simply to obtain more perfect results from washing, and after the nuts and peas have passed through the washing machines they are drained free from water and passed through a large disintegrator, and again mixed with the fine washed

coal from the felspar washers, subsequently being coked in Coppee ovens.

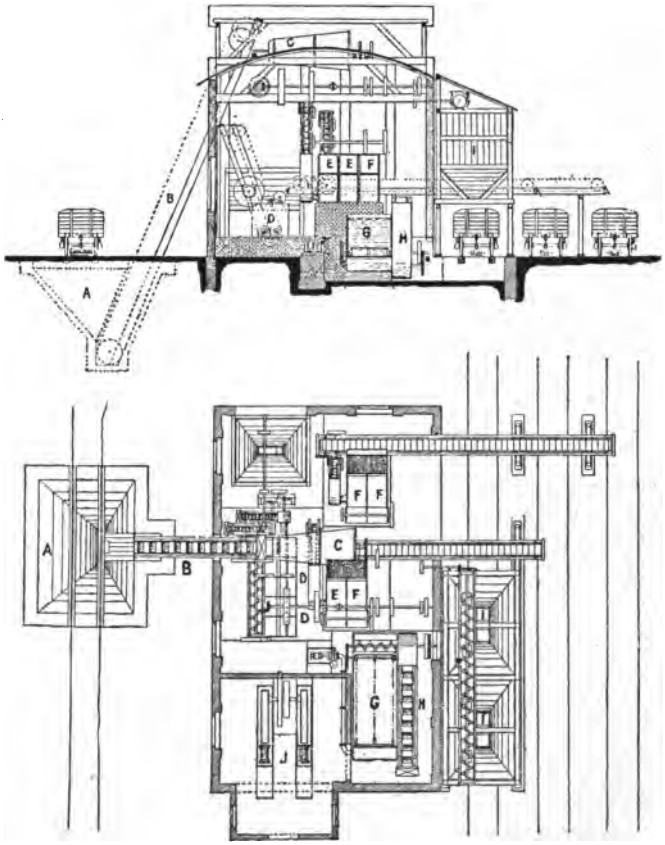


FIG. 197.—Plan and Section of Coal Washing.

The following figures show the results obtained in one week: Coal delivered to washing machine for week, 2,674 tons 11 cwts.; refuse extracted by felspar washing, 125 tons 13 cwts.; refuse extracted by nut and pea coal washing, 133 tons 3 cwts.; total, 258 tons 16 cwts. Average coal washed per day, 445 tons 15 cwts.;

refuse removed by washing, 9·6 per cent.; loss of coal due to washing, 0·25 per cent. on quantity washed; in other words, 5 cwts. per 100 tons. Analysis of coal and coke: Coal before washing, 12 per cent. of ash; volatile matter, 18 per cent.; coal after washing, 5·5 per cent. of ash; coke resulting, 7·4 per cent. of ash.

The coal is raised by the feed-elevator *B* to screen *C*, and is distributed by a trough *D* fitted with right and left screws dividing the fine coal between the 10 felspar washing compartments, *E* and *F* are elevators automatically discharging the refuse from these machines. All the fine coal is deposited in the settling chamber, and from this it is automatically collected and elevated by an elevator *H*. The nut and pea coals pass from the screen into the nut and pea washers *JJ*. The refuse from these machines is released by valves actuated by hand wheels, and is raised by another elevator *K*, so as to discharge into the same bunker as the fine refuse. The whole plant can thus be worked by two men. The engines are a pair of 14 inch diameter by 24-inch stroke, with variable expansion gear.

Trough Washers.—Several systems of washing coal by means of troughs constructed somewhat on the lines of the old trough washers used in the washing of metallic ores are at present in use. Here again the process depends for its success on the varying specific gravities of coal and dirt. Water carrying the unwashed coal flows through a large trough, and is met by trays or screws working in an opposite and upward direction; the result is that the heavier dirt settles in the trays, is carried upwards, and is ultimately deposited in the dirt waggon. The coal freed of its impurities is carried past the trays and finally passes out with the water at the lower end of the trough, where it is recovered by means of settling tanks. Under this heading may be included the **Murton**, the **Elliot**, and for want of a better classification, the **Blackett**.

The Murton Washer.—The makers and patentees of this washer are Messrs. Wood & Burnett, Grange Iron Works, Co. Durham. It is a trough or steam washer, in the arrangement of which a great effort has been made to combine the simplicity and efficiency of the old trough system with perfect washing, absence of waste, and economy of labour. It consists of an endless, jointed, steel trough belt which is water-tight, and revolves slowly around suitable drums fixed at each end. This

trough is about 60 feet long, 3 feet wide and 8 inches deep, and fixed at an inclination of about 1 in 18. Dams or stops about 2 inches high are placed at intervals of 3 feet inside the trough. The trough being set in motion travels up the incline toward the coal and water supply at a speed of 8 to 10 feet per minute. The water carrying the coal flows against the dams, which are thus moving in an upward and opposite direction, and the coal being the lighter body is carried on by the water, the dirt being heavier settles against the dams, and is carried upwards, and ultimately delivered into the dirt waggon. For feeding the coal into the trough a short inclined plate, the **feeding plate**, is arranged immediately below the water nozzle, above which is the coal-supply spout. The water carries the dry coal down the feeding plate, and delivers it with considerable force into the trough. A large portion of the dirt is precipitated quickly, and carried by the moving trough to the dirt waggon, and thus only a short portion of the trough is requisite for the deposition of the dirt, the remainder being free for the further cleaning of the coal.

The Blackett Washer.—The Murton washer may be said to be a travelling trough—the Blackett is a revolving trough. It consists of an iron barrel 25 feet long and 4 feet diameter, with an Archimedean screw on the inner surface. Friction rollers applied to the outer surface cause the barrel to revolve, these being driven by a small steam engine or electric motor. The coal enters the barrel about one-third from the upper end, and a stream of water joins it and carries it down a chute into the barrel. The point at which this unwashed coal enters is regulated according to the amount of washing it requires. A second stream of water joins this at the point where the first stream and the coal enter the barrel. The coal is carried onward by this second current to the outer end of the barrel, the dirt falls downwards into the thread of the screw on the inside of the barrel. The revolution of the barrel is in such a direction that anything falling into it is carried backwards and upwards to the end of the barrel, and thus the dirt is gradually conveyed to the dirt hopper. The coal is thus separated from the dirt, and each is delivered at its own end into trucks in the simplest manner possible. Barrels of the size named will deal with from 100 to 150 tons per day, so that for large outputs several barrels would be needed, but this is

no drawback, as machines can be worked or stopped according as it is desired to turn out a larger or smaller quantity.

Washing Tables.—Two coal-washing tables are in use in England—the **Campbell** and the **Craig**. The former is an American machine, and is almost identical in principle with the latter. A few machines of both kinds have been erected in Yorkshire, but not to the knowledge of the author in any other district. Washers on this principle have the advantage of being simple in construction, and consequently can be bought cheap and worked economically, and as they appear to give quite as good results as the large jigger or trough washers, many more machines of this type may be installed in the future.

The Campbell Coal-Washing Table.—This washing table is the invention of Prof. A. C. Campbell, of Asheville, North Carolina. It is an adaptation of the familiar **bumping** table, with modifications to suit present requirements. It consists of a shallow rectangular box, 9 to 10 feet long by 30 inches wide, swung or suspended near its four corners by rods so as to permit of a longitudinal swinging motion of 6 to 8 inches. The sides of the washer are formed of oak boards 1 inch thick and 12 inches wide at one end and 9 inches at the other, with an oak strip or keel of 2 inches spaced midway between them. Both sides and keel are jointed firmly to a solid head or bumper, shod with a steel plate to withstand wear. The bottom is in two parts and has a peculiar curve. The lower or true bottom is formed of a steel plate securely fastened to both sides and keel. Above the true bottom is a false bottom resting on two side and one central longitudinal strips, and this is formed of galvanized steel plates, bent to form grooves or **riffles**, and about $\frac{1}{16}$ to $\frac{1}{32}$ inch apart. The washing table is hung by the suspension rods at a slight inclination in the direction of the flow of the washing water and coal. Movement is given to the table by a special eccentric.

The unwashed coal after being properly sized is deposited about the middle of the washing table through a chute from the hopper above. Water enters the chute at a convenient height, while a second stream is so arranged as to distribute the water in a fan-like jet over the table. In flowing over the table, the dirt settles to the bottom between the riffles, and the coal is washed over these towards the coal discharge end,

thus so far resembling an ordinary sluice washer with riffles. The jarring action of the table not only stirs up the bed of material, but at the same time gradually works the heavy refuse towards the refuse discharge end. Thus, by means partly of gravity and partly of momentum, the dirt is not only separated from the coal, but both are urged forward in their proper directions.

The table has a capacity of from 5 to 7 tons of washed coal per hour, and 250 gallons of water per hour per ton are required. At a Yorkshire colliery two washeries, each equipped with 56 Campbell tables, are fitted up capable of dealing with 2,500 tons each per day. Careful tests show that the usual amount of refuse extracted is about 6·1 per cent., and this includes 1·5 per cent. of coal.

The Craig Coal-Washing Table.—This table is so like the one just described that only a few details will be necessary to explain its mode of action. Unlike the arrangements of the last named, the coal is thoroughly mixed with the water in a special mixer or **scrubber** before entering the chute. The inclination of the table and the speed at which it is driven are varied to suit the nature of the material to be washed. The length of stroke is usually about 5 inches. A Craig table is capable of dealing with from 4 to 7 tons per hour. It is only suitable for washing coal up to 1½ inches diameter, so that larger coal must first be crushed, but below the size named it is unnecessary to classify first, as the washer works better where the finer stuff can form a bed on which the larger may be gradually shifted forward.

Cost.—Only large and prosperous collieries can afford the price necessary for a large coal-washing plant of the Coppee, Baum, Luhrig or Sheppard types. For dealing with 400 to 600 tons per day, the necessary plant on any of these systems would cost £10,000 or £12,000. A large Humboldt washer is now at work in South Wales capable of dealing with 1,600 tons per day, the cost of which was £40,000.

Trough washers are comparatively cheap; plants large enough to deal with 400 tons per day costing no more than £2,000, while Washing Tables for dealing with a similar quantity would cost probably only £600, exclusive of cost of erection.

The amount paid for maintenance does not vary much. Little attention is needed in any type of washer, and the cost

of driving is generally slight. The cost of washing is probably from about 3d. to 4d. per ton. In some machines where little sizing is necessary, and dirt is not greatly intergrown in the coal, the cost of washing may be less than 1d. per ton. On the other hand, washed coal invariably realises at least 6d. or 7d. a ton more than unwashed. It is true there is loss of weight corresponding to the amount of dirt, etc., taken from the coal.

Coking.—Reference has already been made in an earlier chapter to the nature of coking coals. It has been pointed out that some qualities are peculiarly favourable for coke making, while others are unsuited. It is now only necessary to repeat the definition of coke and to describe the common methods employed for coking. **Coke** consists of the residue of fixed carbon and ash which is left after coal has been heated out of contact with the air, and the whole of its hydrogen, various volatile compounds of hydrogen and carbon, oxygen, water and ammonia, have been driven off. The heavier hydrocarbons and the water and ammonia are, however, collected in the form of **tar** and **ammoniacal liquor**. The lighter hydrocarbons are given off in the form of **coal gas**. Many valuable **bye-products** are obtained from the first-named, such as benzol, naphtha, pitch, bi-sulphide of carbon, sulphate of ammonium, creosote, aniline dyes, etc. These products, as well as the quantity of gas and of ammoniacal liquor, depend upon two things, the nature of the coal and the temperature of coking.

Coking in Heaps.—In this case the coal is piled around a temporary chimney. This is formed of loosely-built bricks, with an iron cover plate for regulating the supply of air. In other cases the heap is covered with earth and moistened coal dust, and openings for the air are made through this as required. Sometimes the coking is allowed to be completed before a cover is put on. Here the pile is ignited at the top, and combustion proceeds downwards, air having free ingress to the mass.

The volatile gases ascend from the lower portion of the heap and prevent the coke from burning until a thin film of ash is noticed, when it is only necessary to cover these parts over with earth or coal dust until the coking is complete.

Beehive Ovens.—Good coke is produced by this method of coking, but in consequence of the admittance of air a smaller quantity results, as some of the coke is burnt. Beehive ovens (Fig. 198)

consist of long rows of circular chambers, built of firebricks, and surrounded by walls to retain all possible heat, the spaces between being filled with sand. Above the ovens runs a small railway for conveyance of tubs containing the coal. The coal is introduced through an opening in the top of the oven, after which the opening is sealed. The chambers vary in size from 8 to 14 feet in diameter at the bottom, having sides vertical to a distance of 2 or 3 feet from where the arch springs, the total height being about 8 feet. Rectangular ovens are also used, the principle being exactly the same. A doorway at the side of the ovens is provided, and when the

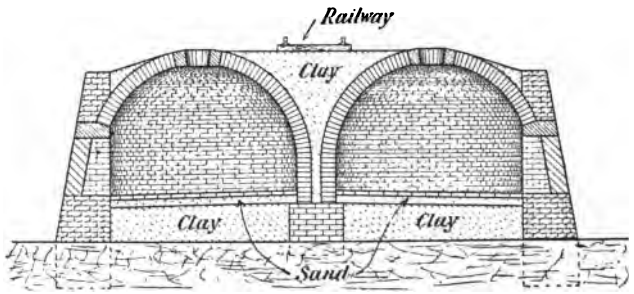


FIG. 198.—Beehive Coke Ovens.

coal is filled in, this doorway is loosely built up, and, if necessary, arranged to admit a small quantity of air. After a few hours the gases from the rapidly decomposing coal are given off, and these are ignited near the top to increase the heat and to obtain more perfect combustion, air being also admitted to the upper portion of the chamber for this purpose. These openings, as well as the lower ones, are afterwards closed one after another, as the gases produced gradually lessen until the heating is complete, after which the coke is allowed several hours in which to cool without being withdrawn and a fresh supply of coal introduced.

The Simon-Carves oven (Fig. 199) may be taken as the standard type of bye-product coke oven in which the combustion of the gases (from which the heat required for the coking process is derived) takes place in horizontal flues, situated in the masonry surrounding the coking chambers.

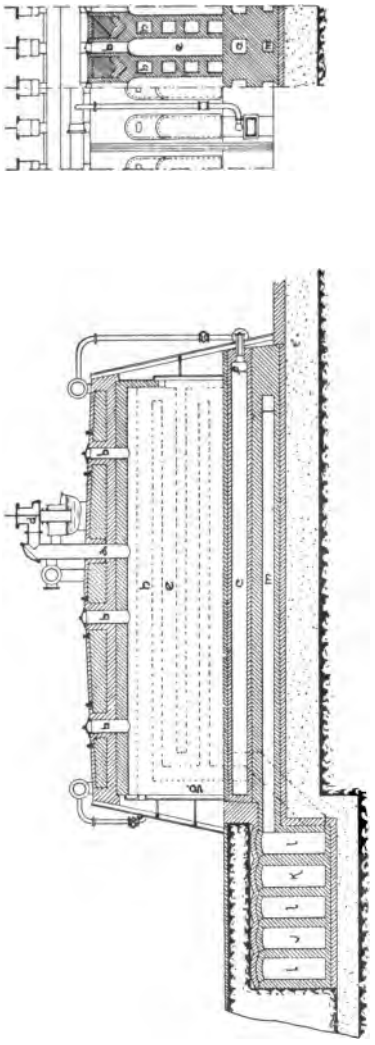


Fig. 199.—Simon-Carves Retort Oven for Coking, with Recovery for Bye-Products.

The oven consists of a rectangular arched chamber *e* about 33-ft. long, 8-ft. 2-in. high, and 1-ft. 8-in. wide. The charge of coal is ten tons at a time. In the top at *b b b* are three charging openings through which coal is introduced from hopper waggons. These openings are closed while the coking process is going on. In the middle of the roof is an opening *a* by which the gases are drawn off through the valve *d* and pass into a gas main of suitable size above the battery of ovens. The gases are drawn off by one or more exhausters, and in order to obtain the valuable bye-products —tar, ammonia, and benzol—are first passed through water-cooled condensers in which they are cooled to atmospheric temperature and the tar removed, and afterwards through scrubbers and washers in which the ammonia and benzol are dissolved out. The gases are then returned to the ovens under which they are burnt, thus supplying the heat

required for coking the coal. The gases enter by nozzles, or tuyeres, into the combustion chamber *f*, where they are mixed with the air required for their combustion. The products of combustion pass backward along the main flue *c* situated under the coking chamber, and then through the vertical flue *g* in the wall between the adjacent ovens, into the top side flue *l*. They then circulate downwards in a zigzag manner through the flues in the oven walls, and finally escape from the oven to the chimney by means of which the draught in the oven flues is maintained. On their way to the chimney the gases pass through the recuperator behind the ovens.

The recuperator consists of a series of parallel gas and air flues *j k* and *l l l* respectively alternating with each other. In this way the air required for the combustion of the gases receives a preliminary heating before entering the ovens. In first starting a new block of such ovens it is necessary to bring the ovens to a coking heat by burning off a few charges in the ordinary manner without the removal of the volatile compounds in the unburnt condition. The combustion of the fuel gases—after this stage has been reached—is sufficient to maintain it.

When once the plant is started the process is continuous, fresh coal being introduced immediately after the removal of the coke. The ovens are built in blocks or batteries, each battery usually consisting of 35 ovens. The yield of coke is fully 15% greater than with the Beehive oven, and the coke is of equal quality, although, owing to its being quenched outside the oven, it does not keep the same silvery appearance as Beehive coke, which is quenched inside the oven. The ovens as described above work off a charge in from 36 to 48 hours, according to the quality of coal coked. The coking is uniform, a high temperature being maintained throughout, and the character throughout the mass of coke varies little.

Charging Retort Ovens.—In the more modern installations, the coal, instead of being put into the ovens through charging holes in the roof, is made into a cake by means of a stamping machine, and is pushed bodily into the oven by mechanical means. The coking then proceeds as described above. In this way, owing to the compression of the coal before charging, a larger quantity can be coked, and a very much denser coke is obtained. By a process similar to that by which the coal cake is inserted into the oven, the mass of coke when the process is

completed is mechanically pushed out by means of a ram. A combined **compressing, charging** and **discharging** machine is shown in Fig. 200, made by the Simon Carves Co., of Man-

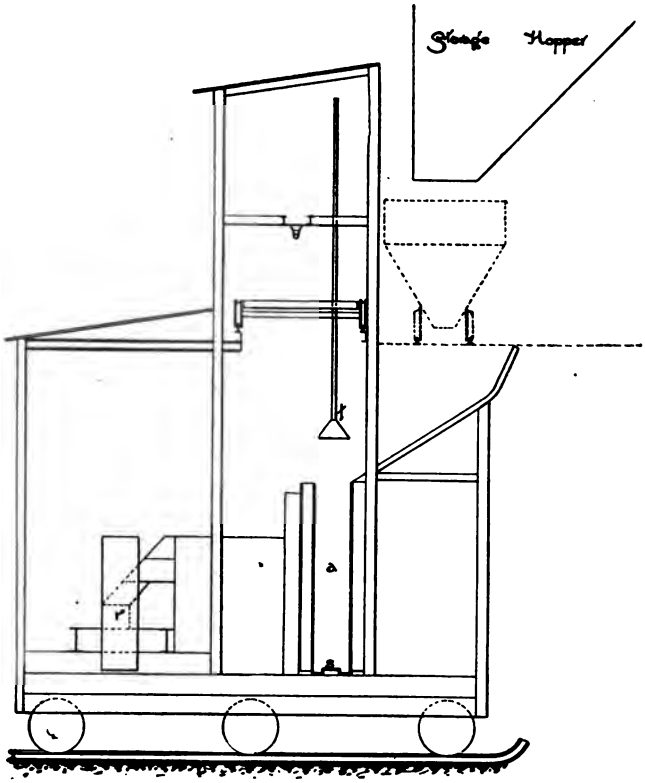


FIG. 200.—Compressing, Charging and Discharging Machine.

chester. The compressing chamber consists of an iron box of the same internal dimensions as the coking chamber, with a movable sole (*s*), actuated by a rack and pinion motion. The moist coal slack is run into this chamber from a storage hopper or from tubs and pressed into a cake by means of a stamper (*t*). The cake is then carried into the oven on the

sole (*s*). The oven door is then closed, thus holding the cake, while the sole plate (*s*) is withdrawn, to allow of which suitable provision is made at the bottom of the door, and the coking process immediately proceeds. When this is completed the mass of coke is pushed out of the oven by means of a ram (*r*), which is actuated by means of a rack-and-pinion motion similar to that fitted to the sole plate.

Briquettes.—Many qualities of small coal which are unsuitable for making into coke have latterly been formed into **Briquettes** or **Patent Fuel**, and in this way coal which was formerly wasted is turned to good use. When treated in a certain way, presently to be described, and formed into suitable rectangular blocks, this small, sometimes inferior, coal becomes of great value for heat generating purposes, and has the advantage of being unaffected by the weather, and is in a most convenient form for storing and handling.

The coal is first screened, and, if necessary, washed, dried and crushed, before being formed into blocks. Large or extremely small and dusty coal is not necessarily the best for briquette manufacture, there being a medium size which is found most convenient. The chief materials used for binding are pitch, starch and lime. The former is the most satisfactory agent, but as its cost is considerably higher than that of the coal, only small quantities can be employed, and that under proper conditions. Briquettes made with pitch are probably hotter, cleaner and less smoky than if made in any other manner, but in general practice a certain amount of the other **binding agents** is used with it. Starch mixed with lime is found to be a good means of binding, and although a rather large percentage of ash is left after burning, the heat generated is usually high, the smoke given off is small, and the cost is considerably less than when formed with pitch. The agent for binding is passed into the cylinder of a machine, and thence driven into another chamber containing the coal, into which steam is also allowed to enter, keeping the coal and agent in constant motion until they are thoroughly mixed. The mixture afterwards passes to the pressing machine, where it is made into rectangular blocks of various sizes, and after being thoroughly dried and, if necessary, waterproofed, is ready for sale.

Calcination of Iron Ores.—Before being placed in the furnace, iron ores are subjected to a process known as

calcination, whereby the ore is heated with a good supply of air in a manner somewhat similar to that of coking coal. This process drives off the volatile gases and reduces the ore to a pliable or more metallic state.

Calcination in Heaps.—Heaps of the iron ore to be calcined are laid on a layer of coal and covered by the small ore, in some cases small coal being mixed with it, especially in ores having no bituminous matter already mixed with them, such as clay ironstones. The heaps are built to a height of 4 or 6 feet, with sloping sides, and when ready they are ignited at the lower portion of one end and allowed to burn until thoroughly calcined, when it is in a more fit condition for being introduced into the furnace.

Kilns are also used for this purpose, arrangements being made for the admittance of the necessary air and for the filling and withdrawing of the uncalcined and calcined ore respectively.

Loading Coal into Ships and Barges.—Coal is loaded into ships and barges from the waggons in various ways:

(1) By means of large cranes which raise the entire waggon, or sections of specially-made waggons, over the hold of the ship, the contents being emptied through a trap-door in the under side.

(2) By means of elevators which raise the coal to a certain height above the vessel, after which it slides down by means of gravity through a shoot into the hold.

(3) By means of specially designed Coal Shippers.

The Wrightson Coal Shipper.—This machine was designed and patented some years ago with the object of avoiding the great breakage of coal resulting from the use of the ordinary gravitation spout. The motion of the coal from the truck on the dock side to the bottom of the hold of the vessel is independent of gravity, and is entirely controlled by machine-driven belts. With a continuous supply of coal, 400 tons per hour can easily be shipped, and this can be increased by a slight increase in the speed of the belts and the capacity of the trays. The coal is first discharged into a hopper immediately below the truck. The first belt, which is horizontal or slightly inclined, moves under the mouth of the hopper, and draws a layer of coal along its surface until it arrives at the side of the quay. At this point it is transferred to the second or jib belt. The frame carrying this belt is hinged at the shore end, so that it can rise

and fall at its outer end to suit the rise and fall of the ship, and has also a slewing motion, right and left, to enable the coal to be directed along the second belt towards any part of the hatch in order to save hand-trimming. At the end of the jib a vertical belt is suspended, which moves in a trunk. This belt has large trays working freely on hinges. These in turning round the top drum form a series of large hoppers or scuttles, the sides of which are the sides of the stationary trunk, and the bottoms of which are the descending trays. As each hinged tray arrives at the bottom of the trunk, it falls open automatically and discharges its contents on the cone of coal forming gradually in the hold. The tray is then carried

FIG. 201.—The Wrightson Coal Shipper.

FIG. 202.—The Wrightson Coal Shipper.

round the bottom roller of the belt in a vertical position, and rises on the outer side of the trunk, until it arrives again at the top roller, when it is automatically turned over, and again receives the coal into the hopper which it forms with the sides of the trunk. By this means a series of huge scuttles is formed automatically, in which the coal quietly descends into the vessel, helped by the force of gravity, but entirely controlled by the machinery. By a suitable arrangement of railway sidings and hoppers, several machines can be arranged so that all the holds in a vessel can be supplied at the same time, thus obtaining extreme rapidity of despatch for vessels. In this case the machines are made to move parallel to the quay and to the lines of railway, so as to plumb any position of hatchway.

Shunting Ropeways for Railway Waggons.—Shunting by means of locomotives is the most common method adopted at the present time, but this has a great many disadvantages, especially on shunting stations or sidings, where one or more locomotives cannot be kept in constant employment.

In the **Heckel Shunting System**, the work is done by an endless rope which runs parallel to the rails, and is guided at a convenient height of about 3 ft. 6 in. By means of a clip and coupling rope the waggons are attached to the rope and carried along to any required position, where the clip and coupling rope is detached. In other respects the arrangement is similar to that of an ordinary mechanical haulage.

The following is a description of a shunting arrangement on the Heckel system (Fig. 203): Loading platforms are arranged on both sides of the siding. The empty waggons lie above the loading platforms and the full waggons below. The centre rails are used for the storage of empty waggons. The empty waggons are first run on the centre rails from the junction *A*. These rails are served by a rope which runs between them and carries the waggons to the top of the siding *B*, where they are switched on to the loading rails as required. Each outside loading rail has a special rope which carries the waggons from the end *B* to the loading platform, and then to the junction *A*. The driving engine is placed in a convenient position close to the rails and about the centre of the siding. The rope travels from and to it in the following manner: the roads from the engine house are named Nos. 1, 2, 3 and 4.

First the rope travels from the engine drum to the end of the siding *B*, where it turns round two pulleys and is guided underneath road 4. It then travels parallel to road 4 to the junction *A*. Just before reaching the junction it clips underneath the latter and on to the siding end *B*, where it turns again and runs along road 1 to the junction *A*, and from here it turns again, slants underneath road 1 and back to the driving engine. Underneath the rails the rope passes along the brickwork trough, and is guided by horizontal, vertical or inclined pulleys. When moving the waggons from the central rails, the momentum gained is sufficient to run the waggons past the switches, where they are then ready to be coupled on to the loading roads.

The driving gear consists of two vertical drums, running on and off at the bottom. After leaving the drum the rope immediately passes round a horizontal tightening pulley. The clips for attachment to the winding rope are so constructed that they can be easily detached with the full load on.

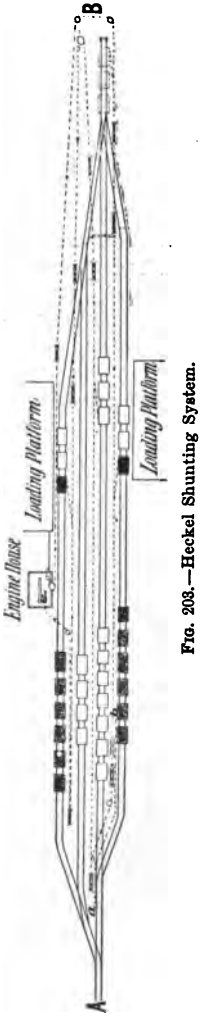


FIG. 203.—Heckel Shunting System.

Questions on Chapter XVII.

1. How is coal that is mixed with shale prepared for the market? (1895.)

2. Notice some arrangements for tipping and screening coal with a minimum amount of breakage. (1897.)

3. Notice some of the principal forms of screens used for sizing coal. (1895.)

4. Sketch out a plant for disposing of the output of a shaft drawing 100 tons of coal per hour, using 10-cwt. tubs and

two-decked cages. The coal to be hand picked and screened but not washed. (1896.)

5. Describe a revolving picking table suitable for picking the refuse from amongst coal or other mineral by hand. Show how its motion of rotation is effected; where the mineral is delivered on to it; and where and how the cleaned mineral is swept off it automatically. (1900.)

6. Upon what principle are most coal washers based? Describe carefully with sketch the mode of working of a good coal washer.

7. What are the main kinds of coal washers used in this country?

8. Describe any method of making coke with which you are acquainted. (1902.)

9. Describe with sketches a good form of Trough Coal Washer.

10. Explain and illustrate by sketches some methods of loading coal into ships with the object of economising time and labour, and as far as possible preventing breakage of the lumps. (1901.)

CHAPTER XVIII.

ACCIDENTS AND DISEASES OF MINERS. LEGISLATION.

It cannot be denied that the miner's calling is a dangerous one, although statistics show that it is not an unhealthy occupation. Fortunately, although there must inevitably be serious accidents occasionally, they are year by year growing gradually less, and whereas the death rate from accidents 50 years ago was 4·5 per 1,000 persons employed, it has now been reduced to about 1·5 per 1,000. During the period of this decreased death rate there has been an increased output of coal. In 1851 the total output of coal was about 50 millions of tons per annum ; it is now about 240 millions of tons. The death rate from accidents for all male persons is about 0·8 per 1,000, and it will be seen therefore that the accident death rate of miners is considerably above the average, but it is not so great as the accident death rate of bargemen, merchant seamen, dock labourers and railway servants. Again, a comparison with the accident death rates of other countries shows that Great Britain has an average considerably lower than that of the United States, Germany and France, both in proportion to the number of men employed and to the output of coal.

Classification of Accidents.—In the Reports of the British Inspectors of Mines, accidents are classified as follows :

1. Accidents from explosions.
2. Accidents from falls of ground.
3. Accidents in shafts.
4. Miscellaneous accidents underground.
5. Accidents on the surface.

The following list shows the average proportions of the total number of deaths due to each respective cause during the twelve years 1893-1904:

DEATH RATE FROM ACCIDENTS IN AND ABOUT ALL MINES PER 1,000 PERSONS EMPLOYED FROM 1893 TO 1904.

Year.	Death Rate from Accidents per 1,000 persons.							Death rate from accidents under and above ground per 1,000,000 tons of mineral raised.
	Underground Workers taken separately.					Employed above ground, from all causes above ground.	Employed under and above ground.	
	Explosions of firedamp or coal dust.	Falls of ground.	Shaft accidents.	Miscellaneous.	All causes underground.			
1893	0·29	0·75	0·19	0·48	1·71	0·90	1·55	6·04
1894	0·56	0·78	0·14	0·31	1·78	0·83	1·60	5·65
1895	0·10	0·75	0·17	0·61	1·64	0·88	1·49	5·17
1896	0·31	0·76	0·12	0·43	1·62	0·91	1·48	4·92
1897	0·03	0·86	0·10	0·50	1·49	0·71	1·34	4·32
1898	0·05	0·76	0·11	0·45	1·37	0·92	1·28	4·22
1899	0·09	0·75	0·12	0·41	1·37	0·79	1·26	3·93
1900	0·07	0·79	0·13	0·45	1·44	0·73	1·30	4·25
1901	0·19	0·74	0·11	0·42	1·46	0·95	1·36	4·76
1902	0·09	0·68	0·15	0·44	1·37	0·72	1·24	4·27
Average for 10 years.	0·18	7·6	0·13	0·45	1·52	0·83	1·39	4·70
1903	0·02	0·84	0·10	0·39	1·35	0·94	1·27	4·41
1904	0·03	0·75	0·12	0·43	1·34	0·85	1·24	4·29

It will be seen that the deaths due to explosions are diminishing. On rare occasions terrible explosions of coal dust or firedamp take place, and throw a whole mining community into mourning. With increased knowledge, however, of the cause of explosions, and the greater precautions taken in these days to prevent them, a considerable decrease in the frequency of their occurrence may be expected; although with the greater depths and consequent increase of temperature, their entire elimination will only be obtained after the best efforts of men of science, mining engineers, managers, and all engaged daily in the mines, have been put forth.

Although the deaths due to explosions, and, in fact, all other causes, have diminished, the deaths due to falls of ground unfortunately show but little diminution. After the passing of the Coal Mines Regulation Act in 1887, there was a sudden decrease in the accidents from all causes, including falls of ground, which fell from 1·12 per 1,000 in 1887 to 0·75 per 1,000 in 1893. Since that time it has remained practically the same, being 0·75 per 1,000 in 1904.

Prevention of Accidents.—Accidents are caused in various ways. Certain things are done *knowingly* which are against the Rules of the Coal Mines Regulation Act, and though a man may do them once or possibly twice without being found out, he is very foolish and deserving of punishment. This he sometimes meets instantly in the shape either of death or of permanent disablement. The desire to *save time* or *labour* in spite of the rules is a most frequent cause of accident. Another class of accidents is due to a fatal habit—*procrastination.* To postpone or delay certain operations—as the setting of a piece of timber—is often a cause of death to many colliers. A miner knows he has room to set a bar or a prop, but he is anxious to get a little more coal, or to fill another tub, and does this heedless of danger. Meanwhile the silent forces of nature are at work, an unseen break or parting is approached, and the roof is down whilst the prop is still unset. Or again, accidents may be due to *errors of judgment*, whereby men are led to risk their lives thinking they are safe. Of course, for errors of judgment there is no absolute cure or preventive; even the best men are liable to err.

On the other hand, accidents may be caused owing to *lack of materials* or *defective materials* and machinery. In this case the victims are seldom to blame, and these accidents can only be avoided by the provision by the management and officials of an adequate supply of suitable and trustworthy materials and plant.

Accidents due to Explosions of Firedamp and Coal Dust.—All the different causes of explosions, and some ways of preventing them, have already been mentioned. It is only necessary here to add that the greatest care must always be taken in shot firing and in inspecting for gas; safety lamps must be of the very best material and workmanship; accumulations of oil or coal dust upon the gauze must be prevented; good

ventilation in the lamp, and care in regulating the light will to a great extent prevent this; while a constant supply of fresh air and well-watered roads will reduce the risk of accumulations of gas or dust; arrangements for distributing the air must be as perfect as possible, and air doors, crossings, etc., should, like the fan, be so placed and arranged as to be injured as little as possible in case of explosions; the impossibility of quickly restoring ventilation after an explosion, owing to the destruction of the ventilating arrangements, is always the cause of great loss of life.

Falls of Ground.—In the chapter on timbering the causes of these accidents and the steps to be taken to prevent them are fully dealt with, and it is only necessary to add here that a plentiful supply of suitable timber must constantly be kept at convenient places; that there must be no delay in carrying out the rules in regard to the supporting of the roof and sides in making places and roadways; that in the drawing of timber the greatest care must be taken, and the mechanical appliance for withdrawing props always used. The new special rule by means of which the colliery manager may fix upon the maximum distances at which props and sprags may be set apart in any mines or parts of mines has greatly improved the safety of the timbering, in those mines at any rate where it is being carefully enforced.

Blasting Accidents.—The accidents from this source are numerous. **Blown-out shots** may be caused by shot holes being in the side, or beyond the holing, or owing to the stemming being too weak. Great care should be taken to avoid these mistakes. The unramming of shots after **misfires** is a wilful breach of the rule, which is frequently punished on the instant by disfigured faces, mangled limbs, eyes blown out, even loss of life itself. Too little care is exercised in the **handling of explosives.** Some explosives are carelessly allowed to freeze, and afterwards are put on an engine cylinder to thaw. Many accidents have been caused through premature explosions under these conditions.

Accidents on Engine Planes, Inclines, etc.—The most effective precaution against this class of accident is to have a second road for travelling. Still, there is danger to those who are occupied in the engine plane or road. Too often, men accustomed to danger, think that they can do more than they are capable of. Meeting a gang of tubs, or being in front of one, they will pass

by one or two or three manholes, thinking they can reach the next. If they prove to be mistaken, a serious accident is inevitable. Sometimes the **trailer** behind a gang is not put on, in the hope that all will go right and smooth; but if a coupling breaks, the tubs will run back, and some one is almost certain to be caught.

Shaft Accidents.—Shaft accidents are caused in many ways—by material being sent down not sufficiently protected from falling out, defective **signalling**, or signals not being understood. Where steam is used underground and signals are required specially for shutting off or turning on steam, it is a good plan to ascertain at least once a week whether everyone remembers the meaning of each signal, as out of a considerable number of men at a large pit, changes are taking place frequently at the mouthings, *i.e.* at the bottom of the shaft and those points in the shaft where tubs are put in the cage, and a new man may be ignorant of the required signal at the critical moment. The same should be done in regard to every special apparatus used at the bottom and needing signals not in the Rule Book. As required by the Act, the top and bottom and every mouthing of a shaft must be securely **fenced**. In respect to this subject the precautions to be taken refer chiefly to times when the fence has to be temporarily removed. For safety to persons getting in and out of the cage at **mouthings**, it is most desirable that all signals should be well understood, as the moving of the cage by the engineer only a little at the wrong time or in the wrong direction may prove fatal.

Surface Accidents.—Fencing of brows and machinery on the surface should be carefully attended to in accordance with the Act. Where the principal road to the shaft by which men descend is not close to the shaft, but where lines of railway are between, there should always be a bridge from the road to the shaft, and the lamp house should be near the bridge. Lines should in no case be crossed by workmen in getting to or from their work.

Accidents due to Electric Shock.—The introduction of electric mains into so many mines has added a new cause of accident, and in some cases, of death. Few miners are as yet familiar with this new power, and it sometimes happens that ignorance of the effect produced under certain conditions causes the miner to receive severe shocks from careless contact

with conductors conveying the current. Many miners have learned, to their cost, the effect of touching the terminals or the brushes of dynamos; it is perhaps fortunate that a shock of insufficient strength to cause death, but of ample strength to make the victim remember the experience for the remainder of his life, should sometimes be experienced to serve as a warning to the careless or inquisitive.

Mr. A. H. Stokes, Inspector of Mines, has made some very wise suggestions for restoring persons suffering from electric shock, and all men in attendance upon electric coal-cutters, pumps, hauling engines, or those engaged in the setting up of electrical installations of any kind, would do well to observe carefully his remarks. He says:

"In cases of shock and insensibility from receiving an electric current through the body, it should be understood that the person may not necessarily be dead, even though his breathing be suspended, but death will soon take place unless the action of the heart and lungs is revived without delay in a similar manner to a person apparently drowned, whose breathing is suspended, and who would die if means were not adopted at once to restore animation. The remedy in both cases is the same, viz., artificial respiration; and as electricity is now being so largely used at mines, and shocks are occasionally received, I think it necessary to caution officials and others that, in case of being called to a person who is apparently dead through receiving an electric shock, they should at once apply the instructions given for artificial respiration, and this should be made widely known to all ambulance men and classes; for while such persons have been taught the system in cases of drowning, I do not find it taught with respect to resuscitation after an electric shock.

"If a man has an electric current passed through his body it generates heat and causes serious muscular contraction, or creates an influence of the nervous system, which controls the heart and lungs, and which remain contracted until the current is taken off; or the charge may strain or rupture some of the organs of the body, which appear to be specially vulnerable to electric currents, or it may rupture a membrane of the body. An electric current continued through the body prevents the heart from acting, and if the current is sufficiently strong, the heart stops, and the man is apparently dead, the actual contact with the body being shown by burning of the flesh.

"There may be a further word of caution inserted here, viz., the

mode of releasing a man from such a position, whether the switch should be used to cut off the current, or an attempt be made to drag the man away. In the former case, electricians tell us that if the switch is used, although only 450 volts may be passing, yet at the moment the contact is broken a man in touch with the machine may receive over 1,000 volts owing to induced current in the motor, and therefore such a method might be fatal to the person being released. On the other hand, if the man's clothes are taken hold of, he could be safely pulled away without injury to his rescuer, and without the least danger to himself.

"The directions for restoring the apparently drowned appear to be, with slight modifications, applicable to those suffering from an electric shock. After the injured man is released from the current, he should be laid upon his back and artificial respiration commenced without delay. After removing all tight clothing from the neck and chest, especially releasing the braces, the instructions for the restoration of breathing must be followed and energetically persevered in for at least an hour, or until a medical man arrives to take charge of the case. There is no necessity to remove the man from the mine, for such a delay may be fatal, and wherever the accident may occur, either down the mine or at the surface, the injured man should be at once placed in a dry place, and artificial respiration commenced as follows:—Dr. Sylvester's method: 'Place the patient on his back, with a small firm cushion, or rolled up article of clothing, under his shoulder blades. Kneel at the patient's head and grasp his arms below the elbows; draw them gently and with a sweeping motion above the head, and cross them; keep them in this position for about two seconds, then carry the arms down on the side of the chest, and press them firmly for about two seconds; repeat the movements steadily and slowly about fifteen times a minute until breathing commences, or until a medical man pronounces life to be extinct. Avoid rough usage, and do not allow the patient to remain on his back unless the tongue is pulled out.—*First Aid to the Injured*, St. John's Ambulance Association."

Recovery of Life.—Under this heading should be included not only the work done after an explosion of gas, or a fall of ground, or an inrush of water has taken place, but the precautions to be taken previously to, or in anticipation of, such accidents, as there is no doubt that many lives may often be saved and much damage avoided by being thoroughly prepared beforehand for disaster of any kind. Few persons have given more thought to this subject than Mr. W. E. Garforth, of

Normanton, who some time ago drew up a number of suggested precautions and rules for the guidance of those in and about mines previous to and during an explosion or a fire, and the student is referred to these very valuable suggestions.*

The precautions to be taken in **anticipation of explosions and accidents** should include:

(1) The appointment of leaders and the formation of corps of rescue parties.

(2) The provision of sufficient supplies and suitable apparatus and machinery for temporary use in case of breakdown of the ordinary plant.

(3) Training of ambulance men and the provision of ambulance supplies.

The work to be done **after an explosion** or other serious accident will include:

(1) The summoning and equipment of all responsible parties, such as the managers, the inspector of mines and all appointed leaders, rescue and ambulance corps.

(2) The fitting up of temporary winding, signalling, ventilating or pumping appliances.

(3) The fixing of cloths, doors, crossings and stoppings for ventilation and the re-setting of timber or other supports which have been damaged or destroyed.

(4) The supply of restoratives to the injured and the carrying of such men to the surface.

(5) The treatment of the injured in hospital or the arrangements for the identification of the dead.

All miners, especially the officials, should go through a course of ambulance instruction. Nothing is more necessary in view of the large numbers of accidents occurring annually below ground than that as large a proportion of the men as possible should have the knowledge necessary to enable them to give first aid to a fellow-worker who has sustained an injury. A great amount of suffering can be avoided, and the time required for the cure of an injury materially shortened by prompt attention. In many cases, a broken limb or a severe bruise has been the cause of death through complication or loss of blood, which would not have resulted fatally if immediate attention by intelligent ambulance men could have been given.

* *Trans. Inst. Min. Engineers*, 1897, vol. xvi., W. E. Garforth.

In all mines, a good supply of ambulance requisites should be provided, consisting of the following: Different sizes of splints, bandages, cotton wool, six rugs or blankets, several flasks fitted with suitable cups and straps for carrying them, water-bottles with straps, supply of brandy, can and cups suitable for supplying hot coffee, hot and cold tea without sugar, cans for oil and lime water, six oxygen cylinders, each capable of holding 3 to 4 cubic feet, sufficient, say, for two men (these cylinders should be made by a respectable firm, properly tested and annealed), 12 small flasks of compressed oxygen, three stretchers (made from two poles and a brattice cloth), two coils of rope of sufficient strength to support a man, six coils of stout cord, six fire-extinguishers, Fluess apparatus or pneumatophor and ambulance waggon. The colliery doctor may desire to have a separate box to contain drugs for his own use, emetics, injections, etc. A similar box, containing most of the articles mentioned, for use near the bottom of the pit, with several portable electric lamps.

In case of accident, instant relief or attention should be forthcoming by ambulance men, and afterwards the sufferer should be carried carefully to the pit bottom and subsequently to the surface. Meanwhile, in serious cases, the manager should be informed, a doctor sent for and the horse ambulance brought to the pit top.

Health and Diseases of the Miner.—In spite of the large number of accidents incidental to his occupation, the miner's calling may be considered a healthy one. Apart from accidents, statistics show that the mortality of coal miners only slightly exceeds that of the most healthy class of workers—gardeners and farmers; and as the collier has to do his work under conditions of the greatest difficulty and of exposure, this appears still more remarkable. Of course, it must be remembered that only those of strong constitution and possessing sufficient physical strength can remain in the mine for any great number of years. The collier's work is so arduous that it must either develop or greatly weaken his physical powers. The conditions under which he works are considerably better now than formerly, but in some of the mines he is subject to extremes of heat and cold, which no doubt affect his health.

Authorities differ as to the effect of coal dust upon the lungs. Dr. Parry says, "Coal dust has a special power of

hindering the development of the germs which cause consumption"; while Prof. Louis says, "Probably the most unhealthy part of the coal miner's work consists in hewing or undercutting the coal, in doing which the collier has to lie on his side on the floor of the coal seam. The collier, working in this position, is also bound to inhale a considerable amount of fine coal dust, which has an irritating effect upon the lungs." Possibly the creosote contained in the coal, which is now recognised as one of the best means of assisting the building up of lung tissue likely to become broken down in tubercular disease, may have a good effect upon the lungs, provided the dust is not breathed in such great quantities as to cause irritation and inflammation of the connective tissue between the air cells. When too much dust is inhaled, irritation and inflammation of the connective tissue between the air cells of the lungs are caused, producing **Coal Miners' Consumption**. Whether creosote has a good effect on the lungs or not, the fact remains, that the comparative mortality of coal miners from lung diseases is lower than in persons employed in any other industry, and from consumption it is even lower than it is from the total lung diseases. The majority of the deaths from lung diseases are no doubt due to the negligence and carelessness of the collier, who will leave his work hot, exhausted and clad in damp, dirty clothes, walk home through the worst weathers and often sit down to eat without first changing into dry apparel. Consequently, it will not be surprising to learn that, although there is an exceedingly low mortality from tubercular disease or phthisis, there is a very high mortality from non-tubercular or inflammatory disease of the lungs.

The table on page 343 shows the comparative death rate of colliers from various diseases.

From this table it will be seen that the chief causes of death among colliers are accidents and lung diseases. Few die through excessive drinking, and fewer still of gout. It will be noticed also that the comparative death rate of all miners is less than that of all males, although in South Wales and Lancashire it is higher, and is higher in fact than that of all males. The healthy condition, however, of the miners of Northumberland, Durham and Derbyshire somewhat makes up for this. It should also be borne in mind that the death

rate is higher than that given below for youths up to the age of 20 and for men over 55, the figures given being for miners of all ages:

	All causes except accidents.	Alcoholism.	Phthisis	Bright's Disease.	Respiratory.	Accidents.	All causes.
Tin Miners,	1,361	4	508	29	377	48	1,409
Lead Miners,	1,267	5	380	33	325	43	1,310
Coal Miners—							
S. Wales,	902	7	107	27	345	243	1,145
Lancashire,	914	5	102	17	389	155	1,069
All Males,	—	—	—	—	—	—	1,000
Occupied Males,	897	13	185	27	221	56	953
Coal Miners—							
Staff.,	817	2	83	22	319	135	952
All Miners,	800	4	109	19	267	135	935
All Coal Miners,	784	4	97	18	269	141	925
Coal Miners—							
Yorkshire,	798	4	123	16	288	114	912
Durham & Northumberland,	678	5	94	15	156	96	744
Ironstone Miners,	688	4	90	15	204	86	774
Coal Miners—							
Derby & Notts.,	638	2	69	8	158	89	727
Farm Labourers,	590	4	115	12	129	42	632

Nystagmus.—During the holing of his coal, the miner's body is in a constrained position. To follow his pick, and to observe exactly where to direct his stroke, his eyes must also be strained greatly. In examining the roof, or testing for gas, the eyes of the fireman and other officials also are subject to strain. This produces an affection of the muscles of the eye called **nystagmus**. The trouble is increased if the lighting is insufficient. Accidents to the eye caused by foreign bodies, such as small pieces of coal flying off from the face, or getting into the eyes during the loading of tubs, are also frequent.

Ankylostomiasis.—Ankylostomiasis, or miner's anaemia, is a disease which has attacked with serious effects the miners of Germany and Italy. It is due to a germ which enters the upper part of the small intestines and there develops, the eggs passing through the bowels and being finally cast out

with the excreta. The eggs then hatch out when the conditions of warmth and moisture are suitable, and the disease, once started, spreads rapidly. The introduction of some Continental miners into British mines caused attention to be drawn to the disease, but it is most likely that our mines will prove unsuitable for its propagation. Cleanliness is the only remedy for this disease. The mine owners in the countries affected provide special baths for their workpeople, and the strictest regulations are enforced whereby the sanitary arrangements both below and above ground may be kept good.

Latrines should be fitted up in all mines, each provided with a small hopper containing a supply of coal dust, a portion of which may be liberated by means of a spring when necessary, in a similar manner to that employed in many towns where dry-earth closets are used. When this is done objectionable smells will be avoided, as nothing is more effective for absorbing the gases than coal dust, consisting, as it does, principally of carbon. The latrines should be emptied regularly, and kept thoroughly clean and disinfected.

LEGISLATION.

Legislation.—Mineral workings are classified as follows:

(*a*) Mines covered by the Coal Mines Regulation Acts, 1887 and 1896.

1. Mines worked for Coal.
2. Mines worked for Stratified Ironstone.
3. Mines worked for Shale.
4. Mines worked for Fireclay.

(*b*) Mines other than those included in the Coal Mines Regulation Acts, 1887 and 1896.

1. Metalliferous Mines.
2. Quarries.

Special Acts of Parliament are in force regulating the working of minerals in this country, but it is only with those affecting the first-mentioned class of mines that the coal miner is concerned.

The Coal Mines Regulation Act, 1887.—This Act, introduced in 1887, is divided as follows: (*a*) Principal Provisions, (*b*) General Rules, (*c*) Special Rules.

The Principal Provisions include various important matters, *e.g.*, employment of men, women and children; the granting of certificates to managers and under-managers; the preparation of plans or surveys of shafts and workings; the provision of shafts; appointment of inspectors; holding of inquests and other enquiries.

Under this branch females and children must not be employed below ground; certificated colliery managers must be appointed at all mines employing more than thirty workmen below ground; proper plans must be prepared and maintained continually; two shafts or outlets must be provided for every mine if over thirty workmen are employed therein.

The General Rules refer to the conduct of all mines within the meaning of the Act, irrespective of the district. They number in all thirty-nine rules, and deal with ventilation; inspection of mine before and during working shifts for gas and other dangers; inspection of machinery; fencing of dangerous places; reports on dangers discovered or safety of mine; use of safety lamps; conditions under which explosives may or may not be used; approaching old workings likely to contain gas or water; signals and signalling apparatus; equipment of haulage, travelling and air roads; timbering of roads and faces; appointment of engineers; equipment of winding shaft, cages and engines; provision of ambulances, etc.; provision of report books; inspections on behalf of workmen; qualifications of coal getters.

The Special Rules.—It is obvious that in the various districts the conditions of working are not always the same. Special Rules are therefore drawn up to suit the special requirements of different districts; although as a rule there is slight difference in their essential features. The Special Rules deal with the following matters:

1. The duties and responsibilities of the Certificated Manager in regard to the control of the mine; the appointment of officials; the publication of notices; the provision of appliances, materials, and report books; and the supply of air for ventilation.

2. The duties and responsibilities of the Under-manager in regard to his share in the control of the mine and other work which may or may not be partly covered by his superior.

3. The duties and responsibilities of Firemen and other competent persons to whom special duties are entrusted in regard to examination for gas, and other dangers, the use of appliances, and obedience to orders of superiors.

4. The duties and responsibilities of miners and all other work-persons in regard to their work, the use of machinery and appliances, and the observance of all rules in regard to the safety of the mine.

5. Rules in regard to safety lamps, explosives, ventilating appliances, machinery, plant, shafts, enginemen, boilermen, banksmen, weighing machines, sinkers and the sinking of shafts.

The Coal Mines (Check-Weighers) Act of 1894.—This is a short Act in which the improper interference with the appointment of check-weighers is made a penal offence. The Check-Weigher is the person appointed and paid by the workmen to do the work, along with the weighman appointed by the colliery proprietor, of weighing the tubs of coal and dirt sent out of the mine by the colliers.

The Coal Mines Regulation Act, 1896.—This is a short Act which amends and supplements the Coal Mines Regulation Act of 1887. It contains further regulations concerning mine plans and safety lamps, the conduct of enquiries before an arbitrator, the prohibition of coal dust for stemming explosive charges. The most important provision of this Act, however, is that known as Section 6. Under this section it is enacted that,

"A Secretary of State on being satisfied that any explosive is or is likely to become dangerous, may, by order, of which notice shall be given in such manner as he may direct, prohibit the use thereof in any mine, or in any class of mines, either absolutely or subject to conditions, and the provisions of the principal Act as to contraventions of General Rules shall apply to contraventions of any such prohibition."

The Explosives Order, 1896.—In pursuance of the power conferred upon him by Section 6 of the last named Act, the Secretary of State in 1896 issued an order known as the Explosives Order, in which the use of certain explosives is prohibited in certain mines, either absolutely or subject to conditions. Only Permitted Explosives are allowed to be used in mines in which inflammable gas had been found within the previous three months in such quantities as to be indicative of

danger. In all coal mines not naturally wet throughout, only permitted explosives are allowed to be used in roads and in dry and dusty parts of the mine.

The conditions under which explosives in all mines may be used are particularly set forth in this Order, and important rules in regard to the supply, storing and use of detonators are included.

Clause 6 of the Order says:

"In this order the term 'Permitted Explosives' means such explosives as are named and defined in the Schedule hereto: provided that where the composition, quality or character of any explosive is defined in such Schedule, any article alleged to be such explosive which differs therefrom in character, quality or composition, whether by reason of deterioration or otherwise, shall not be deemed to be the explosive so defined; provided further that an owner, agent or manager shall not be responsible for the composition, quality, or character of an explosive, if he shows that he has in good faith obtained a written certificate from the maker of the explosive that it complies with the terms of the Schedule, and that he has taken all reasonable means to prevent deterioration of the explosive while stored."

The Special Test to which all explosives are now submitted before being placed on the Permitted List of Explosives for use in coal mines stipulates: (1) the test shall be made at the Woolwich Testing Station, (2) the amount of the explosive to be tested, (3) the conditions under which the test will be made, (4) the conditions under which the explosive will be considered to have passed the test successfully.

A **Permitted List of Explosives** which have successfully passed the Special Test is from time to time published.

The Mines (Prohibition of Child Labour Underground) Act, 1900.—Under this Act the employment of boys below ground under the age of thirteen is prohibited, and this applies to all classes of mines.

The Coal Mines Regulation Amendment Act, 1903.—According to the Act of 1887 a candidate for a certificate of competency as manager or under-manager had to satisfy the examiners that he had had five years' practical experience in a mine. Under this amended Act it is arranged that the Mining Diploma of a University or Mining School approved by the

Secretary of State may be reckoned as the equivalent of two years' experience in a mine.

New Special Rules, 1902.—In 1902 various inspection districts adopted a number of special new rules. The most important of these were rules dealing with the more definite and adequate supply of timber and its more systematic setting and withdrawing (see pages 146 and 150). These rules also include amended regulations in regard to lamps, shot-firing, haulage, waggon-shunting, and the use of electricity in sinking pits.

The Workmen's Compensation Act, 1897.—The principal provisions of this Act are as follows: (1) Liability of certain employers to workmen for injuries. An employer under this Act is liable to pay compensation in case a workman is injured so seriously as to necessitate his being off work for over two weeks.

(2) Time for taking proceedings.

(3) Contracting out. Arrangements are made whereby the employer may under certain conditions contract with any of his workmen that the provisions of a specially arranged scheme of compensation or insurance shall be substituted for the provisions of this act.

(4) Sub-contracting. The owners or proprietors of any works, mines, etc., are under this Act liable to pay compensation in case of injury to the workmen of contractors for any work done on behalf of the owners or proprietors.

(5) Compensation to workmen in case of bankruptcy of employer.

(6) Recovery of damages from stranger.

(7) Application of Act and definitions.

(8) Application to workmen in employment of Crown.

(9) Provision as to existing contracts.

Truck Acts, 1831, 1887, 1896.—The principal Truck Act was an Act to prohibit the payment in certain trades of wages in goods or otherwise than in the current coin of the realm. Amendments were made in 1887 and 1896, but these did not alter the main provision of the original Act. Before this Act was brought into force miners or other workmen suffered many abuses owing to their wages being paid in kind instead of in coin, but at the present time every workman is entitled to receive his wages in coin without any deductions except those to which he has agreed.

Petroleum Act, 1871.—This is an Act for the safe keeping of petroleum and other substances of a like nature, and regulates the time during which, and conditions under which, certain substances may be stored, together with the circumstances under which dangerous stores may be seized or otherwise dealt with.

From the foregoing it will be seen that there is a large number of Acts and Orders regulating the work of the miner and mining officials. A knowledge of these is required by the mining student, not only to enable him to qualify himself for examination, but so that he may be competent to discharge his duties and responsibilities efficiently and faithfully or to see that they are carried out by others.

Questions on Chapter XVIII.

1. How are the various accidents in Coal Mines classified according to the scheme of the Reports of the Inspectors of Mines?

2. What are the commonest accidents in working places underground? (1902.)

3. How do accidents on haulage roads most commonly occur, and how can they best be prevented?

4. How may accidents caused by explosions of firedamp and coal dust be prevented to a certain extent?

5. What are the most common accidents caused by blasting? What precautions should be taken to prevent them?

6. What are the various dangers in the use of electricity in mines, and how may they be guarded against? (Sketches required.) (1903.)

7. What precautions should be taken in anticipation of explosions of firedamp and accidents of all kinds underground, in order that the loss of life and damage to property may be as little as possible?

8. Compare the health and diseases of miners with those of other workers.

9. What is the disease known as miners' anaemia, or ankylostomiasis, which has so severely affected miners in many parts of Europe? What conditions are specially favourable to its propagation and what precautions should be taken to stamp it out? (1902.)

10. How are the various kinds of mineral workings in the United Kingdom classified for legislative purposes? Name the chief Acts of Parliament regulating the working of coal mines in this country.

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